ORDER

6650.10

MAINTENANCE OF FIBER-OPTIC COMMUNICATIONS EQUIPMENT

April 26, 1993

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Distribution: Selected Airway Facilities Field and Regional Offices; ZAF-600

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RECORD OF CHANGES

DIRECTIVE NO. 6650.10

CHANGE TO BASIC	SUPPLEMENT			OPTIONAL	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL

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CHANGE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6650.10
CHG 2

2/2/95

SUBJ: MAINTENANCE OF FIBER-OPTIC COMMUNICATIONS EQUIPMENT

1. PURPOSE. This directive transmits revised pages to extend maximum allowable periodic maintenance intervals. Field offices will retain the control of determining their minimum maintenance intervals.

2. DISTRIBUTION. This directive is distributed to selected offices and services within Washington Headquarters, regional Airway Facilities divisions, the FAA Technical Center, the Mike Monroney Aeronautical Center, and Airway Facilities field offices having the following facilities/equipment: AFSS, ARTCC, ARTS, ASDE, ASR, ATCBI, ATCT, CERAP, EARTS, FOTS, FSS, RAPCO, RBDPE, and TRACO.

3. BACKGROUND. In January 1994, a National Quality Effectiveness Team (NQET) recommended to the Associate Administrator for Airway Facilities (AAF-1) that all national standard maintenance procedures and intervals be revalidated with the goal being a reduction in required maintenance activities and extending the periodicity of intervals. The team's recommendation was subsequently endorsed resulting in these changes.

4. DISPOSITION OF TRANSMITTAL. Retain this transmittal.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
29 and 30	4/26/93	29 and 30	2/2/95
31 and 32	9/30/93	31	2/2/95
		32	9/30/93

James L. Hevelone
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Distribution: Selected Airway Facilities Field and Regional Offices, ZAF-600

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CHANGE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6650.10
CHG 1

9/30/93

SUBJ: MAINTENANCE OF FIBER-OPTIC COMMUNICATIONS EQUIPMENT

1. PURPOSE. This change incorporates the fiber optics equipment installed at the new Denver International Airport into Order 6650.10, Maintenance of Fiber-Optic Communications Equipment. It adds standards and tolerances, maintenance schedules, maintenance procedures, and a list of applicable publications.

2. DISTRIBUTION. This directive is distributed to selected offices and services within Washington headquarters, the FAA Technical Center, the Mike Monroney Aeronautical Center, regional Airway Facilities divisions, and Airway Facilities field offices having the following facilities/equipment: AFSS, ARTCC, ARTS, ATCT, CERAP, EARTS, FSS, RAPCO, RBDPE, TRACO, ASDE, ASR, ATCBI, FOTS.

3. DISPOSITION OF TRANSMITTAL. Retain this transmittal.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
iii and iv	4/26/93	iii and iv	9/30/93
v and vi	4/26/93	v	9/30/93
		vi	4/26/93
vii	4/26/93	vii	9/30/93
5 and 6	4/26/93	5	4/26/93
		6	9/30/93
		6-1 (and 6-2)	9/30/93
27 (and 28)	4/26/93	27 and 28	9/30/93
31 (and 32)	4/26/93	31 and 32	9/30/93
39 and 40	4/26/93	39	4/26/93
		40	9/30/93
43 and 44	4/26/93	43	4/26/93
		44	9/30/93
		44-1 (and 44-2)	9/30/93
51 and 52	4/26/93	51	4/26/93
		52	9/30/93
		52-1 (and 52-2)	9/30/93

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Distribution: Selected Airway Facilities Field and Regional Offices, ZAF-600

Initiated By: AOS-240

FOREWORD

1. PURPOSE.

This handbook provides guidance and prescribes technical standards and tolerances and procedures applicable to the maintenance and inspection of fiber-optic communications equipment. It also provides information on special methods and techniques that will enable maintenance personnel to achieve optimum performance from the equipment. This information augments information available in instruction books and other handbooks, and complements Order 6000.15B, General Maintenance Handbook for Airway Facilities.

2. DISTRIBUTION.

This directive is distributed to selected offices and services within Washington headquarters, the FAA Technical Center, the Mike Monroney Aeronautical Center, regional Airway Facilities divisions, and Airway Facilities field offices having the following facilities/ equipment: AFSS, ARTCC, ARTS, ATCT, CERAP, EARTS, FSS, RAPCO, RBDPE, TRACO, ASDE, ASR, ATCBI, FOTS.

3. MAINTENANCE AND MODIFICATION POLICY.

a. Order 6000.15B, this handbook, and the applicable instruction book shall be consulted and used together by the maintenance technician in all duties and activities for the maintenance of fiber-optic communications equipment. These documents shall be considered collectively as the single official source of maintenance policy and direction authorized by the Operational Support Service.

b. Order 6032.1A, Modifications to Ground Facilities, Systems, and Equipment in the National Airspace System, contains comprehensive policy and direction concerning the development, authorization, implementation, and recording of modifications to facilities, systems, and equipment in commissioned status. It supersedes all instructions published in earlier editions of maintenance technical handbooks and related directives.

4. FORMS.

In addition to the forms required by Order 6000.15B, FAA Form 6000-8, Technical Performance Record - Continuation or Temporary Record/Report Form, is to be maintained for each facility. FAA Form 6000-8 is available from the FAA Logistics Center under NSN 0052-00-686-0001, unit of issue, PD.

5. RECOMMENDATIONS FOR IMPROVEMENT.

Preaddressed comment sheets are provided at the back of this handbook in accordance with Order 1320.40B, Expedited Clearance Procedures for Airway Facilities Maintenance Directives. Users are encouraged to submit recommendations for improvement.

Charles L. Stith
Director, Operational Support Service

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CHAPTER 1. GENERAL INFORMATION AND REQUIREMENTS

1. OBJECTIVE.
This handbook provides the necessary guidance, to be used in conjunction with information available in other handbooks, for the proper maintenance of fiber-optic communications equipment and cable.

2. SAFETY.

a. General. Personnel should observe safety precautions when performing duties on the equipment. For guidance, refer to Order 6000.15B General Maintenance Handbook for Airway Facilities.

b. Uniqueness. In addition to the guidelines established in Order 6000.15B, the following precautions should be observed.

(1) Avoid looking into a laser beam or its reflection (i.e., the beams emitted by an optical time domain reflectometer (OTDR) or an optical transmitter).

(2) In combustible atmospheres, the use of fusion splicers or other spark- or flame-producing equipment should be avoided.

(3) When using solvents to remove buffer coatings, ensure that the work area is well ventilated, safety glasses or goggles are worn, and skin contact with solvents is avoided.

(4) When working with fibers, safety goggles should be worn and care should be exercised to ensure that a piece of fiber does not become imbedded in the eye or skin. In the event that this should occur, seek immediate medical assistance to remove the fiber.

3. AIRCRAFT ACCIDENTS.

a. Following an aircraft accident within the service area of a facility, electronic technicians responsible for the maintenance of equipment in that area must promptly obtain and preserve information that might be needed later. See Order 8020.11A, Aircraft Accident and Incident Notification, Investigation, and Reporting.

(1) Check the Facility Maintenance Log (FAA Form 6030-1) to determine which system units were in operation at the time of the accident. If any unit substitutions have been made since the accident, data on both sets of equipment should be recorded.

(2) Do not make any equipment adjustments until all key performance parameters have been measured and recorded. A separate set of as-left data shall be recorded following any maintenance action that could change as-found conditions. Record the exact nature of any maintenance action.

(3) Record all technical Performance Record (FAA Form 6000-8) data, as found, and any other system parameters considered necessary to establish the operational capability of the system.

(4) Record the following in the Facility Maintenance Log.

(a) As-found characteristics of radar and map videos as they appear on the display.

(b) Any abnormal physical, electrical, or electronic conditions.

(c) Any evidence of anomalous propagation as observed on the display.

(5) Check the key performance parameters and record their exact status in the Facility Maintenance Log or Technical Performance Record.

(6) Certify the validity of recorded as-found/as-left data and all other entries on FAA forms 6000-8

and 6030-1. Also have the witnessing electronics maintenance technician (EMT) or supervisor certify the data, including the date and time of entry.

(7) Review the FAA forms 6000-8 and 6030-1, compile all data pertinent to the accident, and provide the supervisor with this information.

b. It is imperative that all records be kept current, concise, and accurate. These checks shall be made carefully and completed rapidly. All station records, such as facility logs, are official documents. As such, they will be needed during investigations of local aircraft accidents. Additionally, these records will be used for investigating other situations when the operation of the facility is questioned.

4. FACILITY SHUTDOWN.
The mission of the Operational Support Service is to provide reliable airway facilities service for the National Airspace System. Therefore, technicians should be familiar with the procedures and requirements for controlling air traffic when a facility is shut down. Refer to Order 6000.15B for guidance on facility shutdowns. To restore the facility to service, refer to Order 6030.31D, Restoration of Operational Facilities, paragraph 8.

5.-10. RESERVED.

CHAPTER 2. TECHNICAL CHARACTERISTICS

Section 1. GENERAL

11. PURPOSE.

Fiber-optic communications equipment provides a reliable, high capacity, communications path for data, voice, and video signals. Fiber-optic loops are installed at airports to interconnect FAA facilities. These loops provide transmission of radar information to the ATCT, air traffic control communications between the ATCT and air-ground radios, and control and status signals between the ATCT and FAA equipment (navigational aids, lights, engine generators, radar, etc.). The FAA also uses fiber optics in point-to-point applications where a dedicated communications path is required between two facilities.

12. DESCRIPTION.

The basic fiber-optic communications link consists of an optical transmitter and optical receiver, connected by an optical fiber. Figure 2-1 shows this arrangement. The optical transmitter receives an electrical signal and converts it to a modulated optical signal (light wave). This light wave propagates down the optical fiber to the optical receiver, which detects the modulated light and converts it back to an electrical signal.

13. EQUIPMENT TYPES.

a. Fiber-optic equipment may be packaged in a number of ways, depending on the manufacturer.

(1) Optical transmitter. An optical transmitter may be provided as a stand-alone unit (i.e., one module). This device would accept one electrical signal for conversion to an optical signal.

(2) Optical receiver. A stand-alone optical receiver would complement the optical transmitter above. This device would accept an optical signal and convert it to one electrical signal.

(3) Optical transceiver. An optical transceiver operates in both directions, taking in an electrical signal and outputting modulated light and taking in modulated light and outputting an electrical signal. These units may be packaged as stand-alone units or may be modularized and installed in a shelf with other transceivers.

(4) Fiber-optic multiplexers. Fiber-optic multiplexers integrate the multiplexing function and optical conversion into one unit. These units take in multiple electrical signals, multiplex them into one composite electrical signal, then convert this signal to a modulated light wave. The distant end unit receives the optical signal, converts it to an electrical signal, and demultiplexes this signal into the original component signals. The units are typically bidirectional.

b. Fiber-optic cables come in a variety of types and

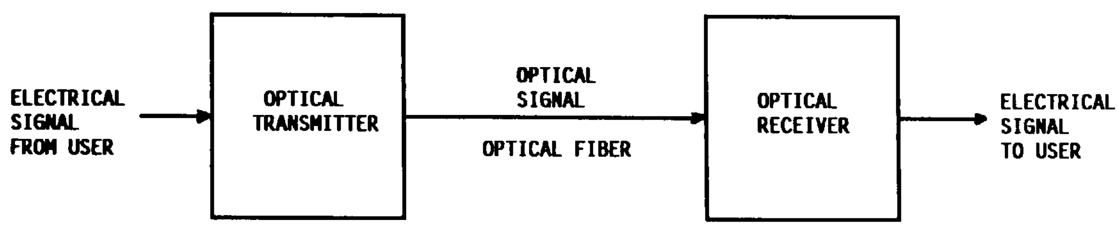


Figure 2-1. Basic Fiber-Optic Communications Link

constructions, which will be described in detail in subsequent paragraphs of this chapter. Specification FAA-E-2761a, Cable, Fiber Optic, Multimode, Multifiber defines six cables for use in the FAA. Cables purchased under this specification will contain optical fibers that are multimode, graded index, 50/125 micron core/cladding diameter.

14. EQUIPMENT CHARACTERISTICS.
The following fiber-optic equipment are presently in use at FAA facilities.

a. Larus Corp DS1 Optical Extension, Model No. FO-1006. The FO-1006 is a fiber-optic transceiver which interfaces four-wire T1 equipment at 1.544 megabits per second (Mbps) to transmit and receive optical fibers. All circuitry is mounted on a card, 12 of which may be installed in a prewired shelf. Major characteristics of the unit are as follows.

(1) Input/Output Electrical Signals - One DS1 (1.544 Mbps).

(2) Optical Source Type - Light-Emitting Diode (LED).

(3) Optical Source Wavelength - 850 nanometers (nm).

(4) Coupled Optical Power (50/125 micron cable) - >-17.5 dBm.

(5) Optical Receiver Sensitivity - -25.5 dBm.

(6) Optical Connector Type - ST.

b. Larus Corp FT2 Quad DS1 Fiber-Optic Extension, Model No. FT2. The FT2 is a fiber-optic transceiver that interfaces four DS1 signals to transmit and receive optical fibers. The units are provided as circuit packs which may be installed in rack-mounted shelves or desktop chassis. Major characteristics of the unit are as follows.

(1) Input/Output Electrical Signals - Four DS1 (1.544 Mbps).

(2) Optical Source Type - Laser.

(3) Optical Source Wavelength - 780 nm (Model FT2-0). 1300 nm (Model FT2-1).

(4) Coupled Optical Power - >-7.9 dBm (Model FT2-0). >-8.9 dBm (Model FT2-1).

(5) Optical Receiver Sensitivity - -23 dBm.

(6) Optical Connector Type - ST.

c. Fibronics International, Inc., Model No. UNIMUX 832. The UNIMUX 832 is a full duplex, time division, fiber-optic multiplexer capable of operating in a point-to-point or loop configuration. The unit uses eight modular channel cards to interface up to 128-voice and data electrical signals. Various channel cards are available to customize a multiplexer to satisfy the circuit needs of the user. These signals are multiplexed into a 20-Mbps data stream and transmitted via optical fiber. An optional backup capability of the unit allows interface to two transmit and two receive optical fibers, which may follow different routes between the multiplexers, thereby providing path diversity. Major characteristics of the unit are as follows.

(1) Input/Output Electrical Signals - Up to 128-voice and data signals dependant on channel cards.

(2) Aggregate Data Rate - 20 Mbps.

(3) Optical Source Type - LED.

(4) Optical Source Wavelength - Optional, 820 or 1300 nm.

(5) Optical Power Budget (coupled optical power to 50/125 micron cable minus receiver optical sensitivity) - 12 dB.

(6) Optical Connector Type - SMA.

d. PCO, Inc., Fiber-Optic Airport Surveillance Radar (ASR) Remoting System, Model No. PCO 5000R. The PCO Model 5000R provides a fiber-optic transmission system (FOTS) between an ASR-8/-ATCBI-5 radar site and the TRACON radar equipment room. The FOTS utilizes three redundant, simplex, fiber-optic links to transmit moving target indicator (MTI) video, normal (NML) video, beacon (BCN) video, azimuth change pulses (ACP), and azimuth reference pulses (ARP) to the TRACON. A redundant, full duplex, fiber-optic link is provided for narrowband sensitivity trigger (NST), voice intercom, and control/readback. Fault sensing and switching circuitry is provided to automatically restore service following an electronic failure or loss of optical signal. The PCO model 5000R uses equipment items from the standard PCO model 5000 video transmission system. These items have been specially modified to interface with the ASR-8/ATCBI-5. Major characteristics of the system are as follows.

(1) Input/Output Electrical Signals - BCN video, NML video, MTI video, ACP, ARP, NST, control/readback, and voice.

(2) Video Frequency Response - +/- 1 dB from 10 Hz to 10 MHz.

(3) Video Gain - Unity (0 dB).

(4) Data Performance - $<10^{-9}$ bit error rate (BER).

(5) Optical Source Type - LED.

(6) Optical Source Wavelength - 1300 nm.

(7) Coupled Optical Power (with SMA connector and 50/125 micron cable) - -18 dBm minimum.

(8) Optical Power Budget (coupled optical power to 50/125 micron cable minus receiver optical sensitivity) - 15 dB minimum.

(9) Optical Connector Type - SMA.

e. Rockwell Digital Multiplex Lightwave System, Model No. DML-45. The DML-45 multiplexes DS1 (1.544 Mbps), DS1C (3.152 MBps), and DS2 (6.312 MBps) signals, or a combination of these signals, into two identical 44.736 MBps DS-3 signals (one main and one backup). It then converts these DS-3 signals into modulated light for transmission over diversely routed optical fibers. In the receive mode, the unit accepts modulated light and provides data in one of the forms listed above. The unit may be used in point-to-point or ring configurations. Major characteristics are as follows.

(1) Input/Output Electrical Signals - DS1, DS1C, DS2, or DS3 as determined by multiplex configuration.

(2) Aggregate Data Rate - 44.736 Mbps.

(3) Optical Source Type - LED (FD-34H/J-7).

(4) Optical Source Wavelength - 1270 nm.

(5) Optical Power Out - -21.5 dBm.

(6) Optical Receiver Power Range (for BER $<10^{-9}$) - -24 dBm maximum, -39.5 dBm minimum).

(7) Optical Power Budget (coupled optical power to 50/125 micron cable minus receiver optical sensitivity) - 18 dB.

f. AT&T FT1, L3 Optical/Electrical Converter. The AT&T FT1 series optical/electrical converter provides for transmission of standard DS1 signals. The units may be housed in small, stand-alone modules, or may be provided as circuit packs for mounting in an equipment shelf. Major characteristics are as follows.

(1) Input/Output Electrical Signals - One DS1 (1.544 Mbps) Alternate Mark Inversion (AMI) or Binary Eight Zero Substitution (B8ZS).

(2) Optical Source Type - Light-Emitting Diode (LED).

(3) Optical Source Wavelength - 1300 nm.

(4) Optical Power into 8.3/125 micron single mode and 62.5/125 micron multimode fiber - -26 dBm average.

(5) Optical Receiver Sensitivity - -45 dBm.

(6) Optical Connector Type - ST (modules); Biconic (circuit packs).

g. Math Associates Digital Transmission System, XD-1000, RD-1000. The XD-1000 is a digital transmitter that converts an electrical data signal to modulated light for transmission through optical fiber. The RD-1000 is a digital receiver which detects modulated light and converts it to an electrical data signal. Together the units form a simplex, point-to-point, fiber-optic transmission path for data. With some electrical interface adaptation, these units are presently used in the FAA to transmit ASR-8/ATCBI-5 ACP, ARP and control/readback signals between sensor and indicator locations. Major characteristics are as follows.

(1) Input/Output Electrical Signals - TTL, RS-232, and RS-422 Data Formats.

(2) Optical Source Type - Light-Emitting Diode (LED).

(3) Optical Source Wavelength - 820 nm.

(4) Optical Power Budget (coupled optical power to 50/125 micron cable minus receiver optical sensitivity) - 10 dB.

(5) Optical Connector Type - SMA.

h. Math Associates Video Transmission System, XV-1500, RV-1500. The XV-1500 is an analog transmitter that will convert a National Television Standards Committee (NTSC) video signal to modulated light for transmission over optical fiber. The RV-1500 is an analog receiver that detects modulated light and converts it to an analog signal. Together the units form a simplex, point-to-point, fiber-optic transmission path for video signals. With some electrical interface adaptation, these units are presently used in the FAA to transmit ASR-8/ATCBI-5 video information via fiber optics.

(1) Input/Output Electrical Signals - 1 v p-p NTSC composite video.

(2) Optical Source Type - Light-Emitting Diode (LED).

(3) Optical Source Wavelength - 1300 nm.

(4) Optical Power Budget (coupled optical power to 50/125 micron cable minus receiver optical sensitivity) - 10 dB.

(5) Optical Connector Type - SMA.

* **i. Racal Datacom, PremNet 5000 Multiplexing Modem.** The PremNet 5000 is a high-speed fiber-optic multichannel video/data/voice demodulator and multiplexer designed for premise network distribution and local area network communications. The unit is made up of equipment configured with plug-in modules for the appropriate types of data being transported. Communications between units is executed over one or more 100-Mbps single mode or multimode fiber-optic links which are divided into twenty 5-Mbps time slots through time division multiplexing. The PremNet 5000 is a software-controlled device. All of its functions are executed via the diagnostic interface to a network management module. Major characteristics of the unit are as follows:

(1) High speed 100-Mbps counter-rotating ring architecture.

(2) Supports 64 ports of 4-wire voice frequency per node.

(3) Supports 32 ports of RS-232, Ethernet, Token Ring, and T1.

(4) Optical source wavelength of 850 or 1300 nm multimode, 1300 nm single-mode.

(5) Supports redundancy on fiber-optic modules, switch modules, and power supplies.

j. Alcatel SONET TM-50/ADM-50, Multiplexer. The terminal multiplexer, 50 Mbps (TM-50), is a digital signal level 1 (DS1)-to-synchronous transmission signal level 1 (STS-1) multiplexer. It is modular, integrated, open architecture, and Synchronous Optical Network (SONET) compliant. The high-speed (51.84 Mbps) port may be equipped with either an electrical STS cross-connect level 1 (STSX-1) or optical carrier *

* level 1 (OC-1) interface. The add/drop multiplexer, 50 Mbps (ADM-50), is functionally identical to the TM-50 system except that the ADM-50 can be equipped with two high-speed interfaces for east and west traffic. Major characteristics of the unit are as follows.

(1) High-speed (50 Mbps) optical or electrical interface.

(2) Low-speed ports support 28 synchronous * DS1 channels.

(3) Redundant clock units, power converters, time-slot multiplexers.

(4) Supports both serial and parallel E2A alarm schemes. *

15.-20. RESERVED

Section 2. FIBER-OPTIC COMMUNICATIONS THEORY

21. INTRODUCTION.

a. Fiber-optic communications is a method of transmitting information from one point to another through thin strands of glass called optical fibers. Digital or analog electrical signals modulate the light output of an opto-electronic device such as a light-emitting diode (LED) or laser. The modulated light is coupled into the optical fiber, which guides the light to an optical receiver. The optical receiver uses a photodiode type device to convert the modulated light into an electrical signal containing the transmitted information.

b. Fiber-optic communications is ideally suited for high density traffic applications as it offers a very wide bandwidth capability which will accommodate video and high digital data rate signals. Many signals can be multiplexed in the frequency or time domain and transmitted via a fiber-optic link.

22. ADVANTAGES OF FIBER OPTICS.
Fiber-optic communications offers the following advantages over copper cable in point-to-point communications applications.

a. Wide Bandwidth. Fiber-optic links offer a higher signal bandwidth than coaxial or twisted-pair runs. This translates to higher channel capacity.

b. Low Loss. Loss in optical fibers remains flat over its specified bandwidth, while loss in coaxial cable or twisted-pair increases with signal frequency. When used with high density traffic requiring higher signal frequencies (bandwidth), optical fiber will exhibit lower loss than copper. This results in fewer repeaters being required to traverse the same distance.

c. Electromagnetic Susceptibility. Optical fiber is not affected by electrical disturbances such as lightning or noise from power lines.

d. Security. Optical fiber does not normally emit energy making it less susceptible to wiretapping.

e. Safety. An optical fiber is a dielectric and does not carry electricity. There are no electrical shock or fire hazards associated with it and it can be used in explosive atmospheres.

f. Light Weight and Small Size. Fiber-optic cables are smaller and lighter than copper cables.

g. Electrical Isolation. Link design is simplified optical transmitters and receivers are electrically isolated from each other. There is no need to maintain a reference potential such as ground at two locations.

23. LIGHT SPECTRUM.

Fiber-optic communications uses light energy in the infrared region of the light wave spectrum. This region lies between visible light and the radio frequency millimeter wave region. Optical fibers and equipment have been optimized to operate in one of three bands of the infrared region. The most frequently used optical carriers in each of the bands are 850 nm, 1300 nm, and 1550 nm. The 850-nm and 1300-nm bands are normally used for short-haul routes such as a local area network or airport cable loop. The 1300-nm and 1550-nm bands are used with single mode fiber in long haul applications such as telecom routes. Note that light waves are normally specified in terms of wavelength rather than frequency. This is done for the sake of convenience, as the frequency of light is so high (850-nm wavelength light has a frequency of 3.5×10^{14} Hz). Also note that since the light is in the infrared region, the output of an optical

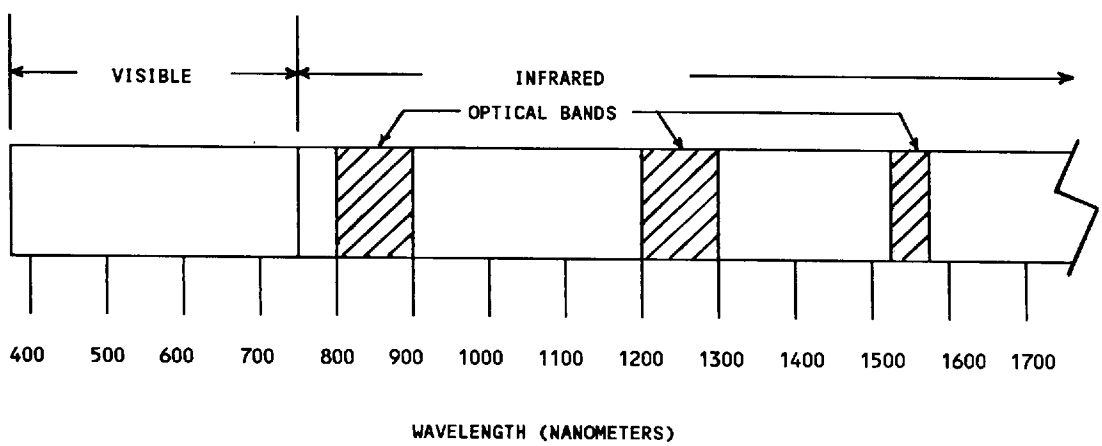


Figure 2-2. Light Wave Spectrum Showing Optical Communications Bands

transmitter and the light in a fiber is invisible to the human eye.

24. LIGHT TRANSMISSION.

a. Light is transmitted between two points using optical fibers. All optical fibers consist of an inner core surrounded by a cladding, such as that shown in figure 2-3. The purpose of the core is to carry the light to its destination. The cladding uses a different refractive index than the core to reflect light waves back into the core. In this way, the light transits down the core of the fiber, bouncing off the cladding layer as it travels. Figure 2-3 represents light transmission down a fiber in its simplest form. However, many factors govern how light is transmitted down a fiber. Figure 2-4 shows a light source and fiber, and tries to illustrate what happens to the optical power out of the source.

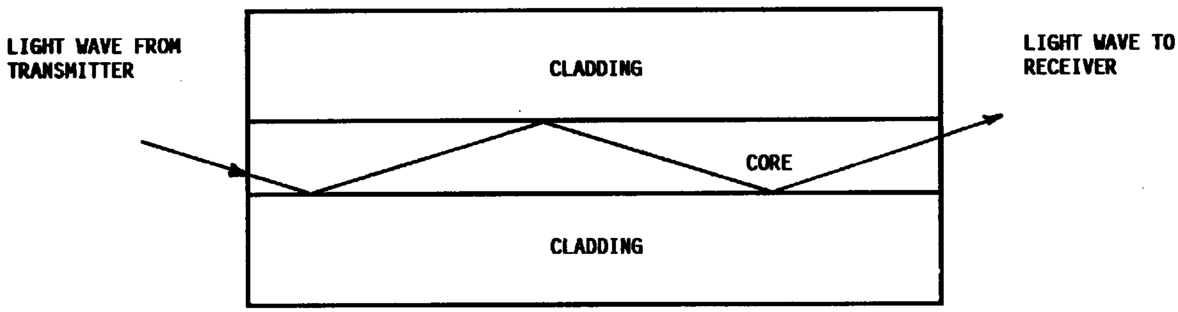


Figure 2-3. Light Wave Transmission through Fiber

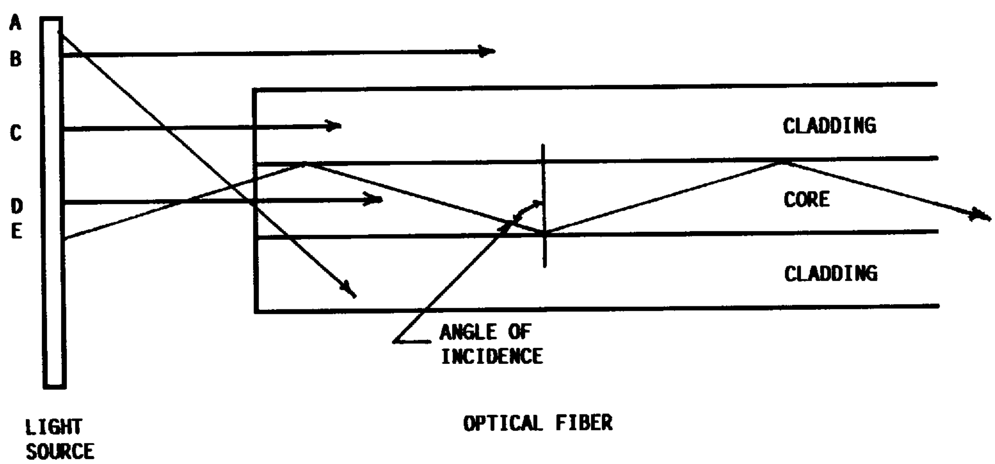


Figure 2-4. Light Wave Coupling to Fiber

b. Light wave A enters the fiber and strikes the core/cladding boundary at too steep an angle. The light wave energy is not reflected back into the core, but is instead absorbed in the cladding and jacket of the fiber. No power is coupled into the optical fiber core. The angle at which a light wave strikes the core/cladding boundary is the angle of incidence. The critical angle of incidence defines the boundary between light waves that are reflected back into the core and light waves that are absorbed into the cladding, and is dependent on the refractive index of the core and cladding materials.

c. Light wave B is launched by the source but does not intersect the optical fiber in any way. No power is coupled into the optical fiber core. Note, however, that this light wave might have been useful had a larger diameter optical fiber been used. The amount of power coupled into an optical fiber is not only dependent on the power level of the light source, but on the size and characteristics of the fiber.

d. Light wave C is launched into the cladding of the optical fiber. The cladding is normally very lossy and this light wave will be attenuated to a negligible level a short distance down the fiber (approximately 10 meters). Care should be taken, however, as a great deal of light may be coupled into the cladding, which could affect test results due to the short cable lengths used in calibration runs. Note, too, that this light wave may have been coupled into the core of a larger diameter optical fiber.

e. Light wave D intersects the fiber core at a right angle to its face and propagates down the fiber without reflecting off the core/cladding boundary. This represents the lowest order mode of propagation down the fiber.

f. Light wave E is launched into the core of the optical fiber at an angle. As the angle is greater than the critical angle of incidence, this light wave is reflected back into the core and propagates down the fiber. This light wave propagates down the fiber at a higher order mode than light wave D. As the angle of incidence of a light wave decreases, the mode of propagation down the fiber increases (becomes higher). Note that as the mode of propagation becomes higher, the light wave is affected as follows.

(1) The light wave has to travel farther to get to the end of the optical fiber. Therefore, light waves that propagate at the higher order modes will be more attenuated at the receiver than those that propagate at lower order modes.

(2) Light waves that propagate at the higher order modes will arrive at the receiver later than those at the lower order modes. This is known as modal dispersion, which affects the bandwidth capability of optical fibers.

25. FIBER-OPTIC LINK DESIGN CONSIDERATIONS.

The purpose of a fiber-optic link is to transmit information from one point to another. To do this, the information must modulate a light source. The light source must couple modulated light into the optical fiber for transmission to the receiver. Sufficient light power must be present at the receiver to permit it to accurately reproduce the transmit information.

a. **Modulation Types**. Information is placed on an optical signal by varying the amplitude of the light. Where a digital signal is applied to the optical transmitter, the signal will cause the optical source to turn on and off, depending on whether a "1" or "0" is being sent. Analog signals such as video or voice will vary the amplitude of the light as the voltage of the signal rises and falls. The optical transmitter and receiver must be selected to condition the analog or digital electrical signal being transmitted to drive the optical source.

b. **Power Budget**. As was stated previously, sufficient light power must arrive at the receiver for it to accurately reproduce the transmitted information. For digital signals, accurate reproduction results in a low bit error rate, while for analog signals a high signal-to-noise (S/N) is desired. Figure 2-5 graphically depicts a power budget. The following factors must be considered in the power budget.

(1) Transmitted Power. The transmitted power is that power coupled into the core of the optical fiber. This level is dependent not only on the output power level of the light source, but on the cable it couples to. One cable factor affecting coupled power level is the fiber core diameter, in which more surface area of the fiber end allows more light to be collected in the fiber. Going from a 50-micron diameter core fiber to one with a 100-micron diameter will increase the coupled

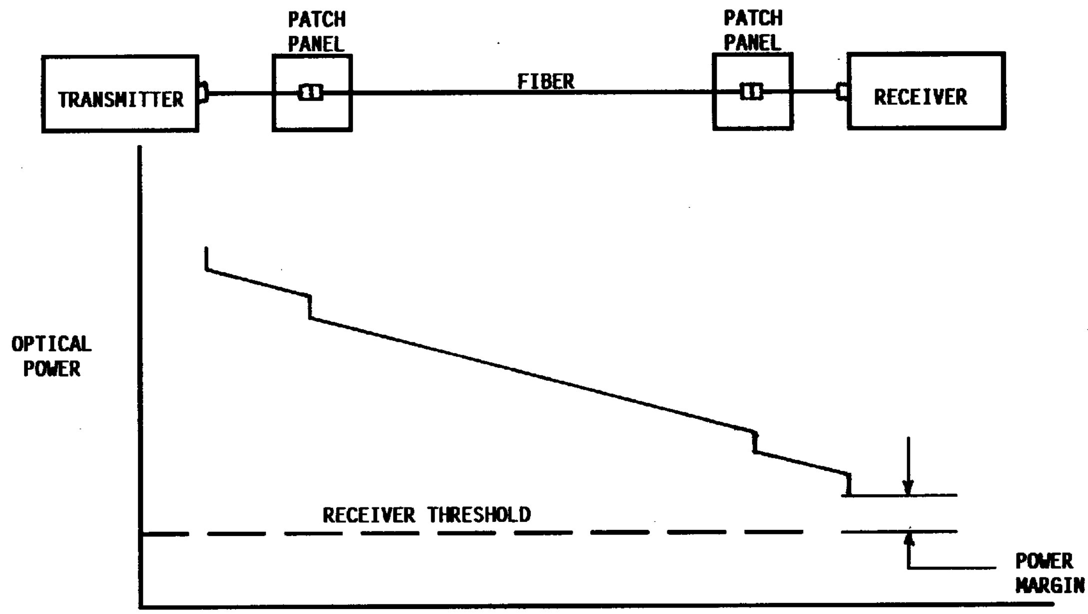


Figure 2-5. Power Budget Model

power by 6 dB. Another factor is the numerical aperture (NA) of the fiber, which is the fiber's ability to accept light rays that are not parallel to the fiber axis. Often, commercial literature on optical transmitters will specify output power in terms of coupled levels for different fiber sizes.

(2) Cable Run Attenuation. Optical fibers attenuate the light signal as it propagates down the fiber. The total attenuation of the signal from transmitter to receiver is the sum of cable loss, splice losses, and connector losses. Cable loss is the product of the length of the run and the attenuation of the fiber per unit length. The attenuation of the fiber per kilometer is dependent on the quality of the cable as well as the wavelength of the light being used. For example, the fiber specified in FAA-E-2761a has an attenuation of 3.5 dB/kilometer (km) with 850-nm light and 1.0 dB/km with 1300-nm light.

(3) Detector Threshold. An optical receiver requires a certain light level at its input to provide an acceptable electrical signal. The amount of light required is the detector threshold and varies for the type and manufacturer of the receiver.

(4) Margin. The margin is the difference between the actual attenuation of the signal between the transmitter and receiver, and the maximum attenuation allowable for proper operation of the link. The margin represents a safety factor, consisting of reserve power to compensate for aging of the source, additional splice losses resulting from cable repairs, and added cable losses due to bends and mechanical stresses. Typical margins for short-run fiber-optic links range from 3 to 6 dB.

c. **Bandwidth**. The bandwidth of a fiber-optic link determines the maximum bandwidth of analog signal or the highest data rate digital signal it may carry. Limits on the bandwidth may be imposed by the electronic equipment associated with the transmitter and receiver, or by the optical fiber run. The bandwidth of an optical fiber run is determined by the mode dispersion and spectral dispersion characteristics of the fiber, as well as the length of the run. For multimode fibers used in the FAA, manufacturers specify bandwidth in terms of a bandwidth-length product such as 400 MHz-km. Ignoring any bandwidth limitations of the transmitter and receiver used, this eans that a signal occupying a spectrum 400 MHz wide may be transmitted down one kilometer of cable. Likewise, a signal of 200 MHz bandwidth may be sent down two kilometers of cable, and a signal of 800 MHz bandwidth may be sent down half a kilometer of cable.

26.-30. RESERVED.

Section 3. FIBER-OPTIC COMPONENTS

31. GENERAL.
This section provides information on the equipment components that comprise a fiber-optic link.

32. OPTICAL TRANSMITTERS.
Optical transmitters use an optical source and drive circuitry to convert an electrical signal into modulated light. The following characteristics describe types of optical transmitters.

a. Source Type. Optical transmitters use either a light-emitting diode (LED) or injection laser diode (ILD) as a source. An ILD provides significantly more power than an LED, typically 0 dBm for an ILD versus -20 dBm for an LED, and is very suitable for long haul applications over single mode fiber. However, an ILD transmitter is much more expensive than one that uses an LED, and the ILD has a much shorter lifespan.

b. Modulation. All optical transmitters use amplitude modulation. In digital data applications, the light source is turned on and off, corresponding to a "1" or "0" bit. For analog signals, the intensity of the light source is varied according to the level of the modulating signal.

c. Applications. Optical transmitters are normally designed for a particular application, such as data transmission, video transmission, or analog voice. The drive circuitry of the transmitter determines the use of the transmitter more so than the LED or ILD. As an example, the drive circuitry of an optical transmitter used for video applications will usually provide preemphasis. Likewise, some optical transmitters such as the Unimux 832 include an integral multiplexer which provide numerous voice and data circuit interfaces.

d. Output Power.

(1) The optical output power of a transmitter is normally specified in terms of "coupled" power to a fiber. It is important to note that the coupled power depends not only on the level of light out of the source, but on the diameter and numerical aperture of the optical fiber it is connected to. The level of coupled power should be used in the power budget calculation. The output power of a transmitter may be specified as follows:

Power Output:
-20 dBm (50/125 micron, 0.20 NA cable)
-15 dBm (62.5/125 micron, 0.27 NA cable)
-11 dBm (100/140 micron, 0.29 NA cable)

(2) Many manufacturers offer options on their transmitters to provide higher power LED's where needed to compensate for long cable runs. FAA specifications presently call for optical transmitters using LED's as a light source.

e. Wavelength. Optical transmitters are specified to provide light centered around wavelengths in the 850-nm, 1300-nm, and 1550-nm bands. However, some manufacturers specify actual wavelength in the neighborhood of these bands such as 780 nm, 820 nm, 1340 nm, and 1510 nm.

f. Spectral Width.

(1) Light sources do not emit light of a single wavelength, but rather a range of wavelengths. The spectral width is defined at the half-power points of the light source output spectrum. For instance, if an

LED puts out light with a peak intensity at 1300 nm and an intensity 3 dB lower at 1260 nm and 1340 nm, its spectral width is 80 nm. The spectral widths for 850-nm LED's are typically 50 nm or less, while the spectral width of 1300-nm LED's ranges from 80 nm to 100 nm. Lasers provide much purer light and typically have a spectral width of 6 nm.

(2) Spectral width becomes an important consideration in the design of fiber-optic links for long-haul or high data-rate applications, as light of different wavelengths travels through optical fibers at different speeds. A pulse of light with a wide spectral width may be generated to transmit a data bit. If the pulse of light is sent down a fiber, the wavelength components of the light will arrive at the receiver at different times, causing the resulting data bit to decrease in amplitude and spread out. If the distance of the fiber is long enough and the spectral width of the source is wide enough, the received data may not be usable. This factor is known as spectral dispersion.

g. Packaging. A fiber-optic transmitter may be packaged in a number of ways, depending on the application. Some units are contained in a small module that may sit on a shelf or mount on a circuit card. Some transmitters are incorporated with a receiver into a circuit card, many of which are plugged into a rack-mounted chassis. Often, a transmitter and receiver are incorporated into an optional output card for a multiplexer, allowing the multiplexer to be used over copper or fiber depending on which output card is used.

33. OPTICAL RECEIVERS.

Optical receivers generate an electrical signal corresponding to the light power present at their input. All receivers basically consist of: a detector, which does the actual conversion of light signal to electrical signal; an amplifier, which increases the relatively weak signal provided by the detector to a usable form; and output circuitry to provide an electrical signal that properly interfaces the user equipment.

a. Detectors.

(1) The most common detector type is the photodiode, which produces electrical current in response to light. Two types of photodiodes used in fiber optics are the pin photodiode and avalanche photodiode (APD). The pin photodiode detector offers an advantage in cost, complexity, reliability, and stability, and is normally used in short-haul routes. Avalanche photodiodes offer better performance in that they have intrinsic amplification. In other words, a small change in light level into the detector produces a large change in electrical signal output of the detector. This results in better noise performance. APD's are normally used in long-haul routes where their responsiveness is required.

(2) In addition to the type of photodiode used, another consideration for detectors is the type of material used. Silicon photodiodes offer the best performance in the 850-nm optical band, but are not suitable for either of the other two bands. Germanium (Ge) and indium-gallium-arsenide (InGaAs) photodiodes are suitable for use in all three bands. InGaAs photodiodes provide slightly better performance at an increased cost. Normally, a Ge photodiode will be used on short-haul routes in the 850-nm and 1300-nm bands while an InGaAs photodiode will be used on long-haul routes in the 1300-nm and 1550-nm bands.

b. Modulation, Wavelength, Applications, and Packaging. The information provided on these subjects in the previous paragraph on optical transmitters also applies to optical receivers.

c. Performance. The performance of an optical receiver is generally stated in terms of sensitivity, also known as threshold, and dynamic range.

(1) The receiver threshold is the minimum amount of optical power required to produce a specified signal-to-noise ratio for analog signals, or a specified bit error rate for digital signals. The threshold is dependent upon the responsiveness of the detector and the noise characteristics of the detector and amplifier circuitry.

(2) The dynamic range of a receiver is the difference between the minimum and maximum levels of optical signals present at the input of the receiver.

The minimum level is the same as the receiver threshold discussed previously. The maximum level is the point at which an increase in optical signal no longer produces a corresponding increase in electrical output, thereby resulting in an output that is distorted with respect to the input. This level may be dependent on the detector being saturated with optical power, or the other electronic circuitry of the receiver being saturated with detector output.

34. OPTICAL FIBERS.

a. Construction. An optical fiber is made up of three basic parts: the core, the cladding, and the coating, as illustrated in figure 2-6.

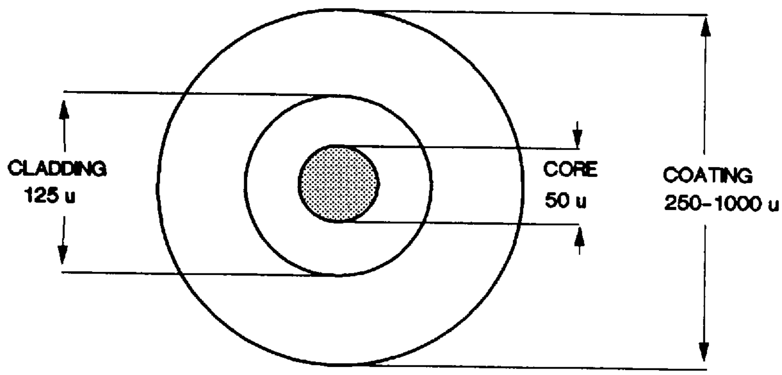


Figure 2-6. Optical Fiber Construction

(1) Core. The core is the central part of the fiber through which light is transmitted and is typically made of silica glass. The amount of light coupled into a fiber is directly proportional to the square of the diameter of its core. In general, the core distinguishes one type of telecommunications fiber from another.

(2) Cladding. Surrounding the core is another layer of glass, called the cladding. The cladding has slightly different optical properties which complement those of the core to facilitate light transmission down the fiber. The index of refraction (or the optical density) of the cladding is slightly lower than that of the core. The cladding influences the path of the light signal through the fiber.

(3) Coating. A polymer coating is used to protect the fiber from abrasion. Coatings are available in thicknesses from 250 microns to 1000 microns and are either mechanically or chemically strippable. The size and composition of the coating are dependent upon the application of the fiber.

b. Size. Optical fiber size is designated by the diameters of its core and cladding. For example, 50/125 describes a fiber with a core diameter of 50 microns and a cladding diameter of 125 microns. Most communications fibers have a cladding diameter of 125 microns (approximately five-thousandths of an inch). A core diameter of 50 microns has been chosen as the standard for FAA installations. Standards do not presently control fiber sizes, but the sizes widely accepted by industry are:

8/125 micron
50/125 micron
62.5/125 micron
85/125 micron
100/140 micron

c. Types. Optical fiber types are characterized by the manner in which light rays travel down the core of the fiber. The two basic types of fiber are the single mode and multimode. Multimode fibers are further broken down into step index types and graded index types. A mode is a path that light rays can follow in traveling down a fiber. Figure 2-7 illustrates how light rays travel down a fiber. The left side of the figure also shows the effect of modal dispersion on a pulse of light.

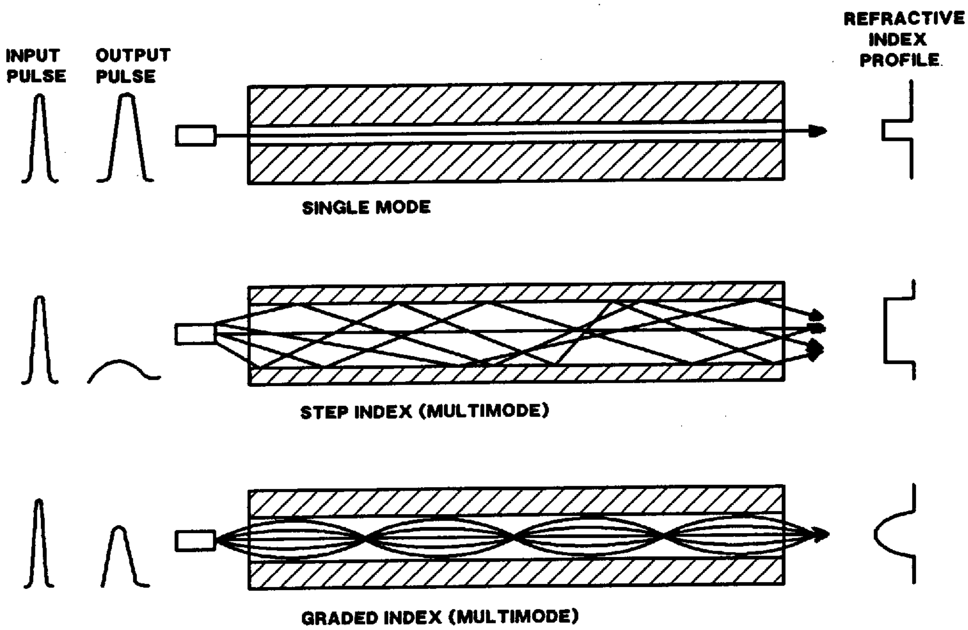


Figure 2-7. Light Propagation in Different Fiber Types

(1) Multimode Step Index Fiber.

(a) The multimode step index fiber gets its name from the distinct, step-like difference in the refractive index of the core and cladding materials. This fiber has core diameters ranging from 100 microns on up, and the index of refraction is uniform throughout the core, making it the easiest fiber to fabricate.

(b) The drawback of step index fiber is its bandwidth limitation due to modal dispersion. The propagation of light down the core may follow a straight line or any number of zigzag paths down the fiber. Light rays following the straight line path arrive at the end of the fiber sooner than those following zigzag paths, due to the different distances they must travel. Therefore, light rays entering the fiber at the same time will exit the other end at different times, thereby spreading out. This spreading is called modal dispersion. The amount of spreading is dependent on the distance of the fiber. Applying this spreading to light pulses, it becomes apparent that if the pulse spreading becomes great enough, one pulse will be indistinguishable from the other. The information in the pulse will be lost. Step index fibers typically limit bandwidth to 20 MHz-km.

(2) Multimode Graded Index Fiber.

(a) Graded index fibers reduce the modal dispersion due to multiple modes by using a material with a lower index of refraction for each successive layer outward from the central axis of the core. As light travels faster in a lower index of refraction, the further light is from the center axis, the greater is its speed. Therefore, light traveling the shortest distance down the center of the core will have the slowest average velocity, while light traveling the farthest distance will have the highest average velocity. All rays tend to reach the end of the fiber at same time.

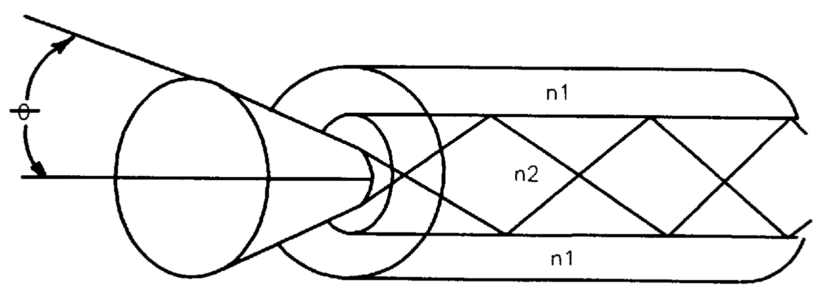
(b) Graded index fibers are more difficult to manufacture than step index fibers, but they offer a bandwidth capability of up to 1 GHz-km. Core diameters of 50, 62.5, 85, and 100 microns are commercially available for these fibers. Multimode, graded index fibers have been chosen as the standard for FAA installations.

(3) Single Mode Fiber. Single mode fibers reduce the core diameter to a point where only one mode of light will propagate. In this way, the effects of modal dispersion are completely eliminated. The bandwidth capability of the fiber is in the tens of GHz-km, and is limited by the electronics associated with it. Single mode fibers come in a standard 8/125 micron core/cladding size and will operate in the 1300 nm and 1550 nm wavelength bands. These fibers are used widely in the telecommunications industry on long haul routes.

d. Characteristics. Optical fibers are characterized by their type (single mode or multimode), size, attenuation, bandwidth, wavelength, and numerical aperture. The first four of these characteristics have previously been discussed in this chapter.

(1) Wavelength. Optical fibers may operate in the wavelengths previously mentioned: 850 nm, 1300 nm, and 1550 nm. Optical fibers specified by FAA-E-2761a are dual-window fibers and as such operate at both 850 nm and 1300 nm.

(2) Numerical Aperture. Numerical aperture (NA) is a measure of the fiber's ability to accept light waves from various angles, and is defined as the sine of the acceptance cone half angle. See figure 2-8. For fibers with equal core sizes, the fiber with the larger NA will accept more light.



$$NA = \sin\theta = \sqrt{n2^2 - n1^2}$$

Where: n1 = Index of refraction of cladding
n2 = Index of refraction of core

Figure 2-8. Numerical Aperture

35. FIBER-OPTIC CABLES.

Optical fibers are packaged in cables to isolate them from external forces and environmental factors. Construction of the cable depends on requirements of the installation for tensile strength, ruggedness, durability, flexibility, size, flammability, and environmental factors such as temperature and humidity.

a. All fiber-optic cables fall into two basic classes, loose buffer and tight buffer. See figure 2-9.

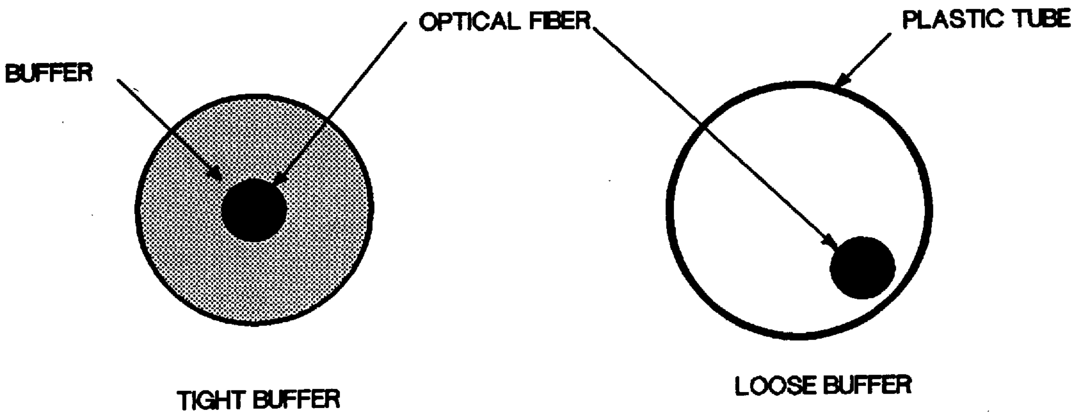


Figure 2-9. Loose Buffer and Tight Buffer Construction

(1) Loose Buffer. In loose buffer construction, the fiber is contained in a plastic tube that has an inner diameter much larger than the fiber itself. The loose tube construction isolates the fiber from mechanical forces that may act upon it. Some cables fill the plastic tube with a gel material to provide further environmental protection for the fiber. Multifiber cables using loose buffer construction may put many fibers in one plastic tube or may use multiple plastic tubes with one fiber in each, covered by an overall jacket.

(2) Tight Buffer. Tight buffer construction uses a direct extrusion of plastic over the fiber coating to protect it from crushing and impact loads.

(3) Performance of Buffer Types. The buffer type to use will depend on the application of the cable. Table 2-1 shows the tradeoffs involved with the two buffer types.

b. Strength Members. Strength members are used in cables to keep the fibers free from stress, and minimize elongation and contraction. Optical fibers do not stretch very far before breaking, so strength members are used to prevent elongation of the cable under tensile loads. Cable strength members typically used in fiber-optic cables include Kevlar aramid yarn, fiberglass epoxy rods, and steel wire. On an equal weight basis, Kevlar is considerably stronger than steel. Kevlar and fiberglass epoxy rods are often the choice when all-dielectric (i.e., no metals) construction is required. Steel is used when cold temperature performance is required.

c. Jacket. The jacket of a cable protects the fibers from the external environment. Many types of plastics are available for use as jackets, and the type of plastic used is dependent on environmental considerations of its installation such as risk of abrasion, exposure to temperature extremes and humidity, exposure to temperature, and flammability. Order 6650.8, Airport Fiber Optic Design Guidelines, lists the jacket material types and the performance tradeoffs associated with each. Metal armor may also be used as a jacket, with a suitable plastic covering, to provide rodent protection in direct burial installations.

Table 2-1. TRADEOFFS OF BUFFER TYPES

CABLE PARAMETER	*LOOSE BUFFER*	*TIGHT BUFFER*
BEND RADIUS	LARGER	SMALLER
DIAMETER	LARGER	SMALLER
TENSILE STRENGTH, INSTALLATION	HIGHER	LOWER
IMPACT RESISTANCE	LOWER	HIGHER
CRUSH RESISTANCE	LOWER	HIGHER
ATTENUATION CHANGE AT LOWER TEMPERATURES	LOWER	HIGHER

d. FAA Specified Fiber-Optic Cables. Specification FAA-E-2761a provides requirements for six types of fiber-optic cables which should satisfy most installation needs.

(1) Type A is a six-fiber, nonarmored, totally dielectric cable having a dielectric strength member. This cable would be suitable for installation in ducts running between facilities.

(2) Type B is a six-fiber armored cable with a dielectric strength member. This cable would be suitable for direct earth burial between facilities.

(3) Type C is a two-fiber, loose tube (loose buffer), non-gel-filled cable. This cable would be suitable for use inside a facility where the performance characteristics of a loose buffer cable are preferable.

(4) Types D and E are similar to types A and B respectively, but they have an additional polyvinylidene fluoride sheath for protection from hydrocarbon fuels. These cables are used where there is a risk of contact with motor vehicle fuels or jet fuels.

(5) Type F is a two-fiber, tight buffer cable. This cable would be used inside a facility where the performance characteristics of a tight buffer cable are preferable.

36. FIBER-OPTIC CABLE RUN. Figure 2-10 illustrates a typical fiber-optic cable run between two facilities. A multifiber cable is run between the two facilities. This cable may be directly buried in the earth, may be installed in cable ducts which are underground, or may use aerial installation between telephone poles. At the building entrance, the cable is routed to a distribution shelf, which may contain a splice tray and fiber-optic patch panel. This distribution shelf serves as the demarcation point between the fibers installed in the building and the fiber installed between buildings. In the distribution shelf, the individual fibers of the cable are separated and spliced onto fiber pigtails, which are routed to the optical patch panel. Individual optical fiber cables are installed between the patch panel and the optical transmitters and receivers. Note that a typical installation would include a second cable run using an alternate route for redundancy. For the sake of simplicity this redundant path is not shown.

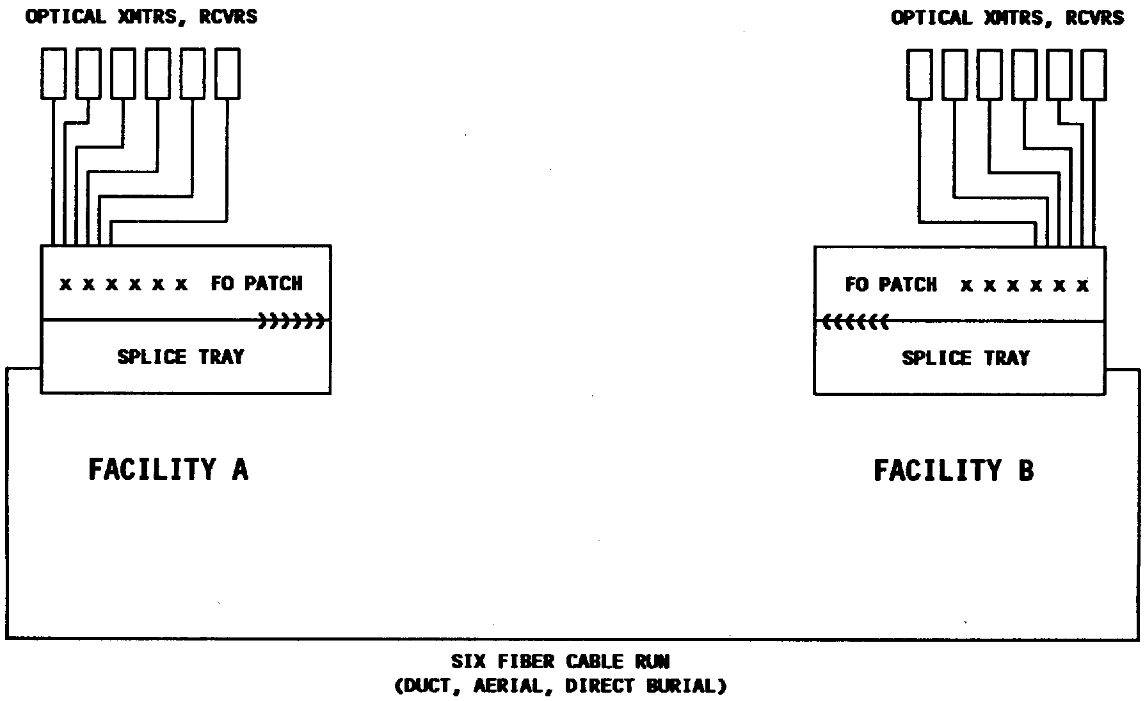


Figure 2-10. Typical Fiber-Optic Cable Run

37. OPTICAL CONNECTORS.

The lack of standardization in the fiber optics industry has led to the use of many types of connectors. These types include the FC, Mini BNC, D4, SMA, ST, SC, Biconic, and FDDI. However, the following types are those most likely to be encountered in FAA facilities. Refer to figure 2-11 for views of the connector types.

a. ST. The ST type connector is available in multimode and single mode versions. This connector uses a keyed bayonet coupling mechanism to accomplish quick connects which are secure and repeatable.

b. SMA. The SMA connector is suitable for use with multimode cable and uses an SMA coupling nut to make a connection. The SMA connector comes in two types, a 905 type and a 906 type. The 905 type has a straight barrel and is used to mate with transmission equipment only. The 906 type has a step-down barrel and may be used when connecting two cables together or when mating directly with transmission equipment. Two plastic sleeves are supplied with each type 906 connector. The short sleeve is used when mating with transmission equipment and the long sleeve is used when mating two type 906 connectors together. The type 906 connector may be used in almost all applications that require an SMA type connector.

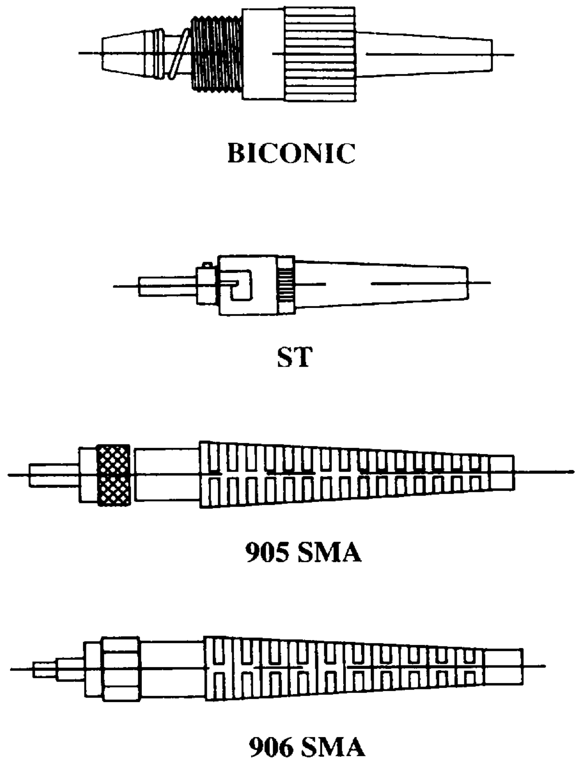


Figure 2-11. Fiber-Optic Connector Types

c. Biconic. The biconic connector is widely used in long-haul telecommunications applications. The connector is available in multimode and single mode versions, and consists of a molded epoxy polymer screw thread and cap, with a spring-loaded latching mechanism.

38. SPLICES.

A splice is a means of joining two lengths of fiber to form one continuous length. It is used during fiber installation to provide a continuous length of cable for a designed cable run. It is also used after installation to repair damaged or defective cable. To be effective, a splice must exhibit low loss and must remain as a permanent part of the optical fiber run. Ideally, the splice should be optically transparent and not subject to degradation over time.

a. **Sources of Splice Loss.** A lossless splice would require that the core areas of the fibers to be spliced be identical, the surface of the fiber ends be clean and flat, and both fibers be perfectly aligned. The following deviations from these criteria will increase the loss in a splice. Figure 2-12 illustrates these deviations. It should be noted that items (1) through (3) result from characteristics of the fiber and cannot be corrected or compensated for by the splice. All splices, however, are designed to minimize items (4) through (7).

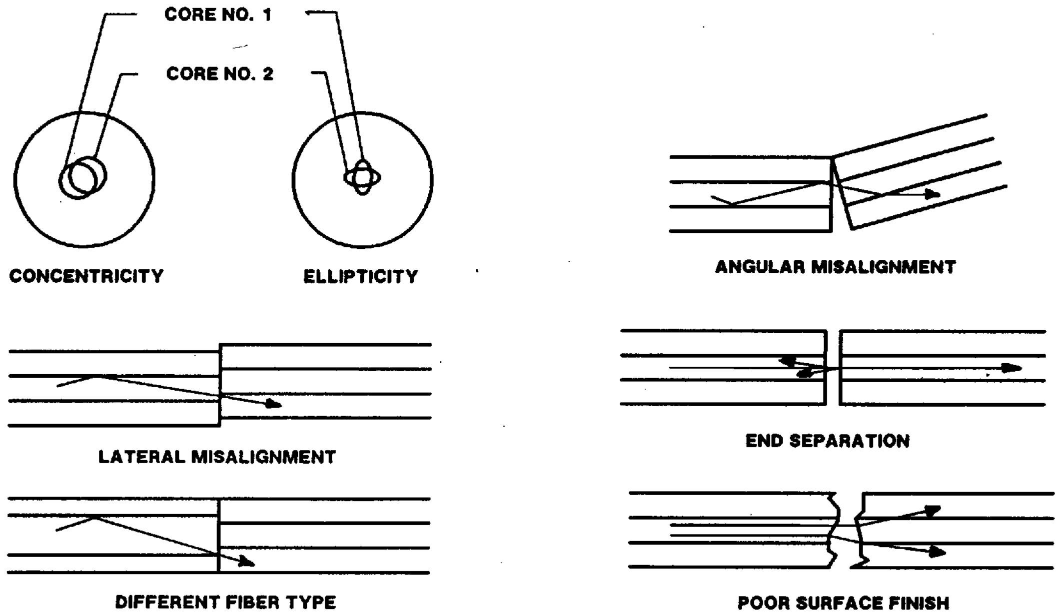


Figure 2-12. Sources of Splice Loss

(1) Different Fiber Types. NA mismatch and core diameter mismatch occur when one type of fiber is spliced to a different type of fiber. Note that the loss due to these mismatches occurs in one direction only. Light transmitted through a fiber with a larger NA or core diameter through a splice to a fiber with a smaller NA or core diameter will be attenuated. Light transmitted in the other direction will not be attenuated.

(2) Concentricity. Loss may occur due to a lack of concentricity in one or both of the fibers to be joined. This loss occurs because the core is not perfectly centered in the cladding. Most splicers line up the fiber based on the cladding, and if the fiber cores are not concentric they will not be aligned and loss will occur.

(3) Ellipticity. Loss due to ellipticity occurs when the fiber cores are elliptical rather than circular. The amount of loss depends upon the relationship between the fiber ends. Rotating one fiber with respect to the other until the elliptical axes are the same will minimize the loss.

(4) Lateral Misalignment. Loss occurs when the axis of one fiber's core does not meet up with that of the other. Some of the light exiting the core of the first fiber enters the cladding of the mating fiber where it is lost after a short distance. A displacement of 10 percent of the core diameter will result in a loss of about 0.5 dB.

(5) End Separation. Ideally, fiber ends should butt in a splice but poor end surface preparation or

splicing techniques may result in a gap between the fibers. This gap results in losses from two sources. First, Fresnel reflections result due to the difference in refractive indices of the fiber material and the gap, which is normally air. The reflections occur both at the exit from the first fiber and at the entrance to the second fiber. Most splices will reduce these losses by using an index matching gel where the fibers meet. This gel has a refractive index the same as the fibers. The second source of loss occurs due to higher order mode rays exiting the first fiber and not falling within the NA of the second fiber. As light exits a fiber conically dependent on the NA of the fiber, a fiber with a high NA will exhibit more loss for the same gap than a fiber with a low NA.

(6) Angular Misalignment. Losses will occur when one fiber is cocked with respect to the other. The mechanism for the losses is basically the same as that for lateral misalignment and end separation.

(7) Poor Surface Finish. Losses will occur when there is poor endface surface preparation. A fractured break rather than a clean, uniformly flat, perpendicular cleavage will prevent the fiber ends from butting and will cause reflections. Scratches instead of a good polished endface will scatter light rays causing reflections and higher order modes of propagation that are dissipated in the fiber cladding.

b. Splicing Techniques. The two basic types of splices used in fiber optics are the fusion splice and the mechanical splice.

(1) Fusion Splice. Fusion splicing uses an electric arc to weld two fiber ends together. This process uses a fusion splicer to align the fibers and perform the fusing. Fiber ends are cleaved and placed in the alignment blocks of the splicer. Some splicers automatically align the fibers (see chapter 7), while less expensive units require the operator to manually align the fibers while viewing them through a microscope. The splicer cleans the fiber ends by using a perfusion arc of low current, then applies the fusing arc to melt the fiber ends together. Typically, losses less than 0.05 dB are achievable using fusion splicing.

(2) Mechanical Splice. There are many types of mechanical splices commercially available: Elastomeric, Rotary, Bent-Tube, CSL LightSplice, etc. The basic difference between the types of splices lies in the method used to align and hold the fiber ends in place. Regardless of the name given to the splice, they all share certain characteristics. A device is used to retain and align the fiber ends. Index matching gel or fluid is used to form a continuous optical path between the fibers and reduce reflection losses. In some cases, ultraviolet (UV) cured adhesive is used to bond the fibers in place making the splice permanent. Other splices hold the fibers together using spring loaded latching devices, which may be disconnected. Still other splices use a splice enclosure to provide mechanical strength for the splice. Typically, losses less than 0.2 dB are achievable using mechanical splicing.

(3) Advantages/Disadvantages.

(a) Fusion splices result in less loss than mechanical splices.

(b) Fusion splicers are relatively sophisticated and expensive pieces of equipment, which may not be cost effective if few splices are required.

(c) Fusion splices are the most permanent as they are environmentally stable and exhibit a high tensile strength.

(d) Mechanical splices provide the faster means to restore a service. If few splices are involved, mechanical splicing techniques are faster. If many splices are necessary, fusion splicing is faster.

(e) Mechanical splicing techniques may be applied in many environments that would be unsuitable for using a fusion splicer, such as rain or wind.

39. ANCILLARY DEVICES.

a. Splice Organizers. Figure 2-13 depicts the use of a splice organizer. These items provide for routing and securing of fibers and splices, as well as securing cable strength members. One or more splice organiz-

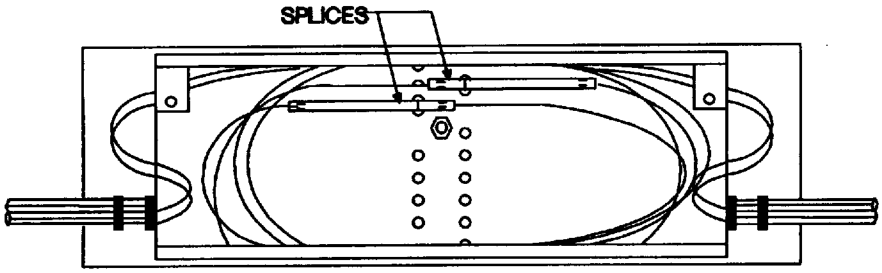


Figure 2-13. Splice Organizer

ers may be contained in a splice closure for mechanical and environmental protection in outdoor or underground installations. Splice organizers may also be configured as splice trays which slide into chassis in indoor installations.

b. Patch Panels. Optical patch panels are provided to provide flexibility in routing fiber runs to equipments. Patch panels generally consist of a panel with feedthrough bushings installed. Connected on one side of the bushing are fiber-optic cables which are dedicated to an optical transmitter or receiver. These connections are meant to be permanent. Fiber-optic cables that run to the distant end facility are connected to the other side of the bushings as required to satisfy the communications need. These connections may be reconfigured as fibers fail or as communications needs change.

c. Distribution Shelf. A distribution shelf consists of a chassis which contains a fiber-optic patch panel and one or more splice trays, thereby providing a single demarcation point between outside plant fibers and inside plant. The distribution shelf simplifies maintenance by providing a single location for patching around failed fibers and fault isolating problems in the optical path.

40.-45. RESERVED.

Section 4. FIBER-OPTIC NETWORKS

46. GENERAL.

Fiber-optic links are used in a variety of ways to satisfy communications needs. The most basic application is the point-to-point configuration where two locations pass information between each other. This type of application for fiber optics is presently used in the FAA to pass video and data from a radar site to a tower or TRACON.

47. NETWORK TYPES.

The point-to-point application is important; however, the high traffic handling capability of fiber optics lends itself to networking, allowing many facilities to communicate with each other by sharing a communications link. Networking may take various forms, as diagrammed in figure 2-14.

a. Bus Structure. The bus structure uses a central communications medium to which each user is connected. This medium is bidirectional, and allows any user to communicate with any other user by accessing the bus.

b. Star Network. A star network uses a central node to which all users are connected. All communications from the users run through the central node,

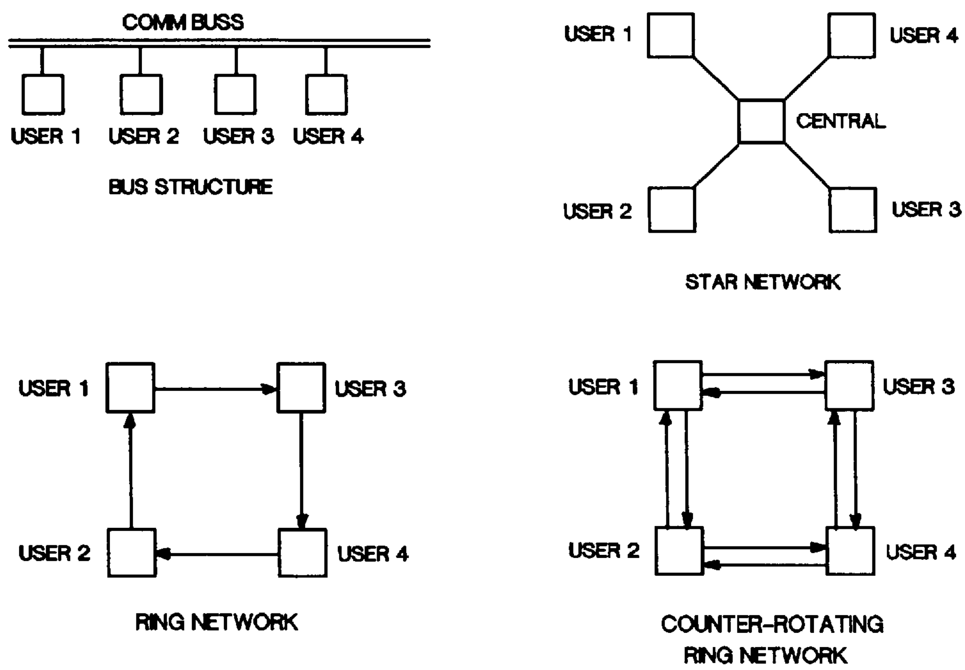


Figure 2-14. Network Configurations

which acts as a switch to route the communication to its intended destination. This network has limited application as failure of the node will result in complete failure of the network.

c. **Ring Network.** A ring (or loop) is a closed path transmission system which has each user connected serially with one on either side of it. Communications flow from user to user in only one direction around the ring.

d. **Counter-Rotating Ring.** The counter-rotating ring configuration uses two loops. Communications in one loop flows in a clockwise direction, while in the other loop it flows counterclockwise. This method provides the most reliability, as the communications path is fully redundant and a break in the link will not affect network communications.

48. NETWORK CONTROL METHODS.

When two or more facilities share a communications path, such as occurs in a network configuration, a method of control is required to govern which facility is to have access to the communications path at any given time. Various protocols are used to enable this control and are described briefly as follows.

a. **Token Ring.** This method of network control uses a token which is passed from user to user along the network. The user can only access the network when he has the token.

b. **Time Division.** In the time division protocol, discrete time intervals assigned to each user. A user may transmit only during its time interval. This method of protocol requires all users on the network to be synchronized in time.

c. **Carrier Sense Multiple Access with Collision Detection (CSMA/CD).** This protocol gives access to the network to each user equally. A user first listens to the network to detect transmission by another user (carrier sense). If another user is transmitting, the first user will not transmit but will continue to listen until the network is not busy. In the event that two terminals listen, sense an empty network, and transmit, the messages will collide and become garbled. Collision detection is used to cause the garbled message to be ignored and inform the users of the need to retransmit their messages.

d. **Master-Slave.** In this protocol, one user in the network is designated a master while all others are slaves. The master transmits messages on the network containing an address corresponding to one of the slave users, as well as the information to be sent. The message is received by all slave users and the address portion decoded. Only the slave who is addressed evaluates the information and responds to the master. Note that this protocol allows communications only between slave users and master, not between slave users.

49. AIRPORT CABLE LOOP.

Airport cable loops, which are networks found on larger airports, provide communications connectivity between the various facilities located around the airport. Order 6650.8, Airport Fiber Optic Design Guidelines, provides information on the design of these cable loop systems. Many of the cable loops presently installed or planned will be fiber-optic based and will use the counter-rotating ring network configuration. This configuration is recommended due to the critical nature of the traffic being transmitted on the link. Figure 2-15 shows the airport cable loop planned for the Atlanta Hartsfield Airport. Note that an airport cable loop system may include more than one loop, with each of the loops configured for counter-rotating ring operation. Also note the different facilities interconnected by the loop, and the fact that the loop will be used for control and status signals from the various equipments as well as air/ground communications.

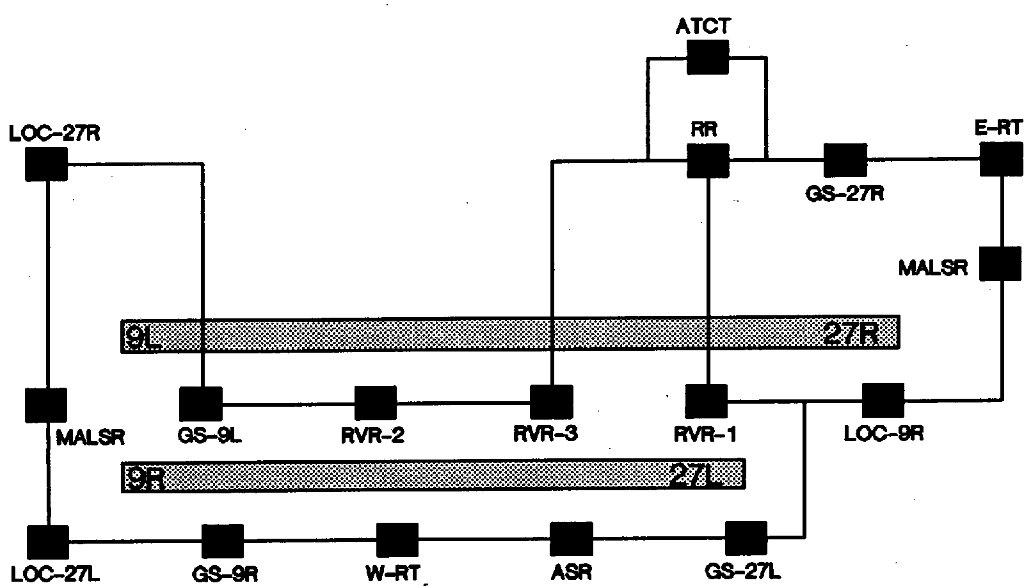


Figure 2-15. Airport Cable Loop Sample Layout

50.-55. RESERVED.

CHAPTER 3. STANDARDS AND TOLERANCES

56. GENERAL.

This chapter prescribes the standards and tolerances for fiber-optic communications equipment, as defined and described in Order 6000.15B. All key performance parameters and/or key inspection elements are clearly identified by an arrow placed to the left of the applicable item.

Parameter	*Reference Paragraph*	*Standard*	*Tolerance/Limit*	
			Initial	*Operating*
→ **57. OPTICAL FIBER ATTENUATION.**	117	Commissioned value	<3 dB degradation	Same as initial
58. LARUS DS1 OPTICAL EXTENSION, FO-1006.				
a. Data Speed	–	1.544 Mbps	±200 bps	Same as initial
→ **b. Bit Error Rate (aggregate or any data channel)**	–	$<10^{-9}$	Same as standard	Same as standard
c. Transmitter Optical Power Output (coupled to 50/125 micron cable)	–	Commissioned value (>-17.5 dBm)	Same as standard	<3 dB degradation
→ **d. Received Optical Power**	120	>-25.5 dBm	Same as standard	Same as standard
59. LARUS QUAD DS1 FIBER-OPTIC EXTENSION, FT2.				
a. Data Speed (each DS1)	–	1.544 Mbps	±200 bps	Same as initial
→ **b. Bit Error Rate**	–	$<10^{-9}$	Same as standard	Same as standard
c. Transmitter Optical Power Output (coupled to 50/125 micron)	–			
(1) Model FT2-0	–	Commissioned value (>-7.9 dBm)	Same as standard	<3 dB degradation
(2) Model FT2-1	–	Commissioned value (>-8.9 dBm)	Same as standard	Same as standard
→ **d. Received Optical Power**	120	<-7 dBm, >-23 dBm	Same as standard	Same as standard

Parameter	Reference Paragraph	Standard	Tolerance/Limit Initial	Tolerance/Limit Operating
60. FIBRONICS INTERNATIONAL, UNIMUX 832.			Same as standard	Same as standard
a. Data Channels				
(1) Data rate	--	Commissioned value	Same as standard	Same as standard
→ (2) Bit error rate	122	$<10^{-9}$	Same as standard	Same as standard
b. Voice Channels				
→ (1) Loss (1004 Hz)	121	0 dB	±0.3 dB	±0.6 dB
→ (2) Frequency response	121	<0.6 dB deviation	Same as standard	<1.2 dB deviation
→ (3) Idle noise	121	<16 dBrnc0	Same as standard	Same as standard
→ c. Received Optical Power	120	Commissioned value	<3 dB degradation	Same as initial
61. PCO FIBER-OPTIC AIRPORT SURVEILLANCE RADAR (ASR) REMOTING SYSTEM, PCO 5000R.				
→ a. Video Gain	123	Unity	±3 dB	Same as initial
→ b. Video Bandwidth (+0, -3 dB)	123	100 Hz to 12 MHz	Same as standard	Same as standard
c. Transmitter Optical Power Output (coupled to 50/125 micron cable)	--	Commissioned value (>-18 dBm)	Same as standard	<3 dB degradation
→ d. Received Optical Power	120	>-33 dBm	Same as standard	Same as standard
62. ROCKWELL DIGITAL MULTIPLEX LIGHTWAVE SYSTEM, DML-45.				
a. Data Speeds	--			
(1) DS1 line		1.544 Mbps	Same as standard	Same as standard
(2) DS1C line		3.152 Mbps	Same as standard	Same as standard
(3) DS2 line		6.312 Mbps	Same as standard	Same as standard
→ b. Bit Error Rate	--	$<10^{-9}$	Same as standard	Same as standard
c. Transmitter Optical Power Output (FD-34H/J-7 module coupled to 50/125 micron cable)	--	Commissioned value (>-21.5 dBm)	Same as standard	<3 dB degradation

Parameter	*Reference Paragraph*	*Standard*	*Tolerance/Limit*	
			Initial	*Operating*
→ **d. Received Optical Power**	120	< −24 dBm, > −39.5 dBm	Same as standard	Same as standard
63. AT&T FT1, L3 OPTICAL/ ELECTRICAL CONVERTER.				
a. Data Speed	–	1.544 Mbps	±200 bps	Same as initial
→ **b. Bit Error Rate**	–	$<10^{-9}$	Same as standard	Same as standard
c. Transmitter Optical Power	–	Commissioned value (> −26 dBm)	Same as standard	<3 dB degradation
→ **d. Received Optical Power**	120	> −45 dBm	Same as standard	Same as standard
64. MATH ASSOCIATES DIGITAL TRANSMISSION SYSTEM, XD-1000, RD-1000				
a. Data Speed	–	Commissioned value	Same as standard	Same as standard
→ **b. Bit Error Rate**	–	$<10^{-9}$	Same as standard	Same as standard
→ **c. Received Optical Power**	120	Commissioned value	<3 dB degradation	Same as initial
65. MATH ASSOCIATES VIDEO TRANSMISSION SYSTEM, XV-1500, RV-1500.				
→ **a. Input Signal Level**	–	1 V p-p	±0.3 V	Same as initial
→ **b. Output Signal Level**	–	1 V p-p	±0.3 V	Same as initial
→ **c. System Bandwidth (+0, -3 dB)**	124	100 Hz to 10 MHz	Same as standard	Same as standard
→ **d. Received Optical Power**	120	Commissioned value	<3 dB degradation	Same as initial
* **66. RACAL-DATACOM, PREMNET 5000.**				
a. Data Speed	–	Commissioned value	Same as standard	Same as standard
b. Bit Error Rate (optical and data ports).	122	$<10^{-9}$	Same as standard	Same as standard
c. Optical Power Output (coupled to 50/125 micron cable).				
(1) 1310 nm, multimode, 15 dB	–	≥ −20 dBm	Same as standard	<3 dB degradation *

Parameter	Reference Paragraph	Standard	Tolerance/Limit	
			Initial	Operating
* (2) 1310 nm, single mode, 25 dB	–	≥ −8 dBm	Same as standard	<3 dB degradation
d. Received Optical Power (coupled to 50/125 micron cable).				
(1) 1310 nm, multimode, 15 dB	120	≥ −26 dBm	Same as standard	Same as standard
(2) 1310 nm, single mode, 25 dB	120	≥ −24 dBm	Same as standard	Same as standard
e. Voice Channels.				
(1) Loss (1004 Hz)	121	0 dB	±0.3 dB	±0.6 dB
(2) Frequency response	121	<0.6 dB deviation	Same as standard	<1.2 dB deviation
(3) Idle noise	121	<16 dBrnc0	Same as standard	Same as standard
67. ALCATEL, SONET TM-50/ADM-50.				
a. Data Speed	–	Commissioned value	Same as standard	Same as standard
b. Bit Error Rate	122	$<10^{-9}$	Same as standard	Same as standard
c. Optical Power Output, FTM108 Transceiver.	–	≥ −13.5 dBm	Same as standard	<3 dB degradation
d. Optical Power Input, FTM108 Transceiver.	120	≥ −31.7 dBm	Same as standard	Same as standard
68.-75. RESERVED.				*

CHAPTER 4. PERIODIC MAINTENANCE

76. GENERAL.

This chapter establishes all the maintenance activities that are required for fiber-optic communications equipment on a periodic, recurring basis, and the schedules for their accomplishment. Section 1 identifies the performance checks (i.e., tests, measurements, and observations) of normal operating controls and functions, which are necessary to determine whether operation is within established tolerances/limits. The second section identifies other tasks that are necessary to prevent deterioration and/or ensure reliable operation. Refer to Order 6000.15B for additional guidance.

Section 1. PERFORMANCE CHECKS

	Performance Check	*Reference Paragraph*		
		Standards & Tolerances	*Maintenance Procedures*	
	77. OPTICAL FIBER.			
	a. Annually. Measure attenuation of fiber-optic cable between transmitter and receiver.	57	117	
	b. As Required. Measure cable performance using optical time domain reflectometer (OTDR). Measurement shall be made at cable installation to establish a baseline. Subsequent measurements shall be made when cable loss exceeds tolerance specified and after corrective maintenance is performed on a cable.	–	118	
	78. REDUNDANT PATHS.			
*	**Semiannually.** Check operation of spare devices and cables.	–	119	*
	79. LARUS DS1 OPTICAL EXTENSION, FO-1006.			
*	**a. Monthly.** Check indicator lamps for proper operation	–		*
	b. Annually. Measure optical power at receiver	58d	120	
	80. LARUS QUAD DS1 FIBER-OPTIC EXTENSION, FT2.			
*	**a. Monthly.** Check indicator lamps for proper operation			*
	b. Annually. Measure optical power at receiver	59d	120	
	81. FIBRONICS INTERNATIONAL, UNIMUX 832.			
*	**a. Monthly.**	–	–	*
	(1) Perform lamp test, using front panel pushbutton.			
	(2) Check indicator lamps for proper operation. Refer to the Unimux 832 System Operation Manual to determine proper indications for configuration installed.			

Section 1. PERFORMANCE CHECKS (CONTINUED)

Performance Check	*Reference Paragraph*	
	Standards & Tolerances	*Maintenance Procedures*
b. Annually.		
(1) Measure optical power at receiver	60c	120
(2) Measure 1004-Hz loss for each voice channel	60b(1)	121
(3) Measure frequency response of each voice channel	60b(2)	121
(4) Measure idle noise of each voice channel	60b(3)	121
(5) Measure bit error rate of unused data channels	60a(2)	122
82. PCO FIBER-OPTIC AIRPORT SURVEILLANCE RADAR (ASR) REMOTING SYSTEM, PCO 5000R.		
* **a. Monthly.** Check indicator lamps for proper operation.	–	– *
b. Annually.		
(1) Verify system video gain and bandwidth	61a, 61b	123
(2) Measure optical power at receiver	61d	120
83. ROCKWELL DIGITAL MULTIPLEX LIGHTWAVE SYSTEM, DML-45.		
* **a. Monthly.**	–	– *
(1) Perform lamp test by pressing and holding the HIST switch on the DX-78G display.		
(2) Check indicator lamps for proper system operation.		
b. Annually. Measure optical power at receiver	62d	120
84. AT&T FT1, L3 OPTICAL/ELECTRICAL CONVERTER.		
* **a. Monthly.** Check indicator lamps for proper operation.	–	– *
b. Annually. Measure optical power at receiver	63d	120
85. MATH ASSOCIATES DIGITAL TRANSMISSION SYSTEM, XD-1000, RD-1000.		
Annually. Measure optical power at receiver	64c	120
86. MATH ASSOCIATES VIDEO TRANSMISSION SYSTEM, XV-1500, RV-1500.		
Annually.		
a. Measure video bandwidth	65c	124
b. Measure system gain	–	125

Section 1. PERFORMANCE CHECKS (CONTINUED)

Performance Check	Reference Paragraph: Standards & Tolerances	Reference Paragraph: Maintenance Procedures
c. Measure optical power at receiver	65d	120
87. RACAL-DATACOM PREMNET 5000.		
* a. **Monthly.** Check indicator lamps for proper operation.	–	126 *
b. **Annually.**		
(1) Measure optical power at receiver	66d	120
(2) Measure 1004-Hz loss for each voice channel.	66e	121
(3) Measure frequency response for each channel.	66e	121
(4) Measure idle noise of each voice channel.	66e	121
(5) Measure bit error rate of unused data channels.	66b	122
88. ALCATEL SONET TM-50/ADM-50.		
* a. **Monthly.** Check indicator lamps for proper operation.	–	126 *
b. **Annually.**		
(1) Measure optical power at the receiver.	67d	120
(2) Measure bit error rate of unused DS1 channels.	67b	122
89.-95. RESERVED.		

Section 2. OTHER MAINTENANCE TASKS

Maintenance Task	*Reference Paragraph*	
	Standards & Tolerances	*Maintenance Procedures*
96. FIBRONICS INTERNATIONAL, UNIMUX 832.		
Annually. Adjust multiplexer receiver sync potentiometer R206.	–	131
97. MATH ASSOCIATES DIGITAL TRANSMISSION SYSTEM, XD-1000, RD-1000.		
Annually. Align RD-1000 receiver	–	132
98.-105. RESERVED.		

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CHAPTER 5. MAINTENANCE PROCEDURES

106. GENERAL.

This chapter establishes the procedures for accomplishing the various essential maintenance activities which are required for fiber-optic communications equipment, on either a periodic or incidental basis. The chapter is divided into three sections. The first section describes the procedures to be used in making the performance checks listed in chapter 4, section 1. The second section describes the procedures for doing the tasks listed in chapter 4, section 2. The third section describes the procedures for doing special tasks, usually nonscheduled and not listed in chapter 4. Refer to Order 6000.15B, General Maintenance Handbook for Airway Facilities, for additional general guidance.

107. TEST EQUIPMENT.

The testing of fiber-optic communications equipment requires the use of some unique items of test equipment. Prior to performing the maintenance procedures listed in this chapter, the technician should read chapter 7 of this handbook to become thoroughly familiarized with manufacturer's operating manuals on the test equipment being used.

108. GENERAL INSTRUCTIONS.

a. Cleanliness of optical surfaces is extremely important when performing fiber-optic measurements. The maintenance procedures contained herein frequently direct the technician to clean connectors using alcohol and lint free pads. Note: Standard rubbing alcohol is not recommended for use with optical equipment due to its lack of purity. Alcohol recommended for use with fiber optics should be completely denatured or reagent grade, 190 proof (95 percent pure).

b. When performing power measurements using test equipment and cables equipped with SMA connectors, a problem was experienced with repeatability, as multiple measurements of the power produced varying results. This problem can be traced to the fact that the mating ends of a connection are not locked into place with this type of connector, (i.e., the fiber end faces may be rotated with respect to each other), and the ellipticity of, and variations in, the surface of the fibers will affect the measurement. The following observations were made during validation of the procedures.

(1) Changing the orientation of the fiber connection to the power meter had no effect on the reading.

(2) Rotating fiber ends of a cable-to-cable connection produced a maximum deviation of 0.4 dB.

(3) Rotating the orientation of the fiber connection to the optical source resulted in a deviation of up to 6 dB. It is not known whether this deviation is caused by the particular optical source being used; however, it will not affect the measurement so long as the connector is not moved after the calibration loop and before the measurement is made.

109. PRECAUTIONS.

a. Do not look directly into a laser light source or into a fiber-optic cable end. Laser light is invisible. Viewing it directly does not cause pain. The iris of the eye will not close involuntarily as when viewing a bright light. Serious damage to the retina of the eye is possible.

b. Cleaved glass fibers are very sharp and can pierce the skin very easily. Do not let cut pieces of fiber stick to your clothing or drop in the work area where they may cause problems. Use tweezers to pick up cut or broken pieces of glass fibers, and place them in a loop of tape kept for that purpose.

c. Wear safety glasses to protect the eyes from accidental injury when handling chemicals or cutting fibers.

d. When using solvents to remove buffer coatings, ensure that the work area is well-ventilated and that safety glasses are worn. Avoid skin contact with solvents.

e. Avoid using fusion splicers in combustible atmospheres. Never spray solvents or other cleaning agents into electrode or lens area. The fusion arc may ignite the gas.

110.-115. RESERVED.

Section 1. PERFORMANCE CHECK PROCEDURES

116. FAA FORM ENTRIES.

Order 6000.15B contains policy, guidance, and detailed instructions for field use of FAA Form 6000-8, Technical Performance Record. Entries shall be made in accordance with instructions published in Order 6000.15B.

117. FIBER-OPTIC CABLE ATTENUATION.

a. Object. This procedure measures the loss of the fiber-optic cable, including connectors, between the transmitter and receiver.

b. Discussion. The attenuation of the fiber-optic cable is measured by injecting a known optical power level into the fiber and measuring the power level out of the fiber. The measurement is conducted in two steps. First, the optical source is connected through a launch cable to the power meter, and a reference power level (the input power level) is established. Second, the optical source is connected through a launch cable to the fiber under test. The power meter is connected to the other end of the fiber and a power level is read. The difference between the input power level and the level out of the fiber is the loss. The following guidelines apply to this test.

(1) The optical source used should match the type and wavelength of optical transmitter that is used in operation. For example, if the optical transmitter uses an 850 nm wavelength LED, then the optical source test device should use an 850 nm wavelength LED.

(2) The test should be conducted on the fiber in the same direction the fiber is used in normal operation. The optical source should be connected to the fiber end that is normally connected to the optical transmitter. The power meter should be connected to the fiber end that is normally connected to the optical receiver.

(3) The launch cable is used for two purposes. It provides the proper connector interface between the optical source and the fiber-optic cable. Additionally, six turns of the launch cable are wrapped around a 0.5-inch diameter cylinder, creating a mode filter. In this way, it reduces the effect of cladding power and higher order modes on the measurement, thereby increasing accuracy and repeatability.

c. Test Equipment Required. The following items are required to perform this test.

(1) Optical Source. The optical source should be of the same type (LED or laser) and wavelength as that used in actual operation over the fiber under test.

(2) Optical Power Meter.

(3) Launch Cable. Some manufacturers provide launch cables which may be used with different optical fibers. If a launch cable is to be purchased, ensure that it is usable for the type of fibers to be measured. A launch cable may be manufactured by taking 5 meters of fiber-optic cable of the same type as the fiber to be measured (e.g., 50/125 micron, multimode, graded index, 0.20 NA) and attaching connectors to mate with the optical source on one end and the fiber under test on the other.

(4) Mandrel. A cylinder of approximately 1/2-inch diameter is required to create a mode filter. The length of the cylinder is not critical so long as it will accommodate six turns of the launch cable.

(5) Adapters. Adapters may be needed to interface the test equipment to the cable. A male-to-male connector may be required to interface the launch cable to the test cable. This male-to-male connector may consist of a small plastic sleeve which slides over the connector barrel.

d. Detailed Procedure. Two individuals are required to perform this test, one located at the transmitter and one at the receiver. Communication between the two individuals must be maintained during the test. The test loss measured should include all fibers and connectors between the optical transmitter and the optical receiver.

(1) Place service on a backup fiber or coordinate a system outage with air traffic.

(2) Clean all connectors prior to testing with alcohol and lint-free pads, or with treated pads made for the purpose.

(3) Ensure that the optical source is turned off.

(4) Set source for proper wavelength for test. Set calibration of power meter for the wavelength of the source in accordance with the power meter manufacturer's instructions.

(5) At the optical transmitter location, connect the launch cable to the optical source. Wrap six turns of the launch cable around the mandrel to make a mode filter, and connect the launch cable to the optical power meter. See figure 5-1. Use connectors and bushings as required.

(6) If applicable, zero the power meter reading in accordance with the manufacturer's instructions.

(7) Turn the source on and let stabilize for 5 minutes.

(8) If the source is adjustable, set it to a convenient reading on the power meter. Do not readjust this setting for the duration of the test. If the power meter has a "dB REF" capability, store the reading for later use. If the power meter does not have this capability, record the reference reading in dBm or dBu.

(9) Turn the optical source off and disconnect the launch cable from the power meter. Do not disconnect the launch cable from the source.

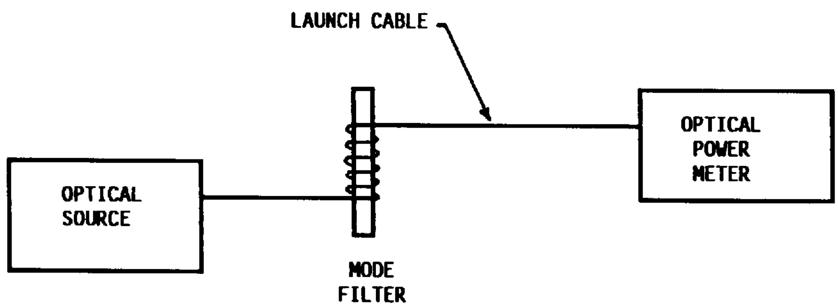


Figure 5-1. Cable Loss Measurement Calibration Setup

(10) At the transmitter location, turn off the optical transmitter feeding the fiber under test. Disconnect the fiber to be tested from its associated optical transmitter and connect it to the launch cable. At the receiver location, turn off the optical receiver associated with the fiber under test. Disconnect the fiber under test from its optical receiver and connect it to the power meter. See figure 5-2. Use connectors and adapters as required.

(11) Turn on the power meter and ensure that it is still calibrated for the wavelength to be used. Zero the power meter.

(12) Turn on the optical source and measure the power out of the fiber under test. If the power meter has a "dB REF" capability, the loss may be read directly on the meter. If not, subtract this reading in dBm or dBu from the reference reading in dBm or dBu recorded

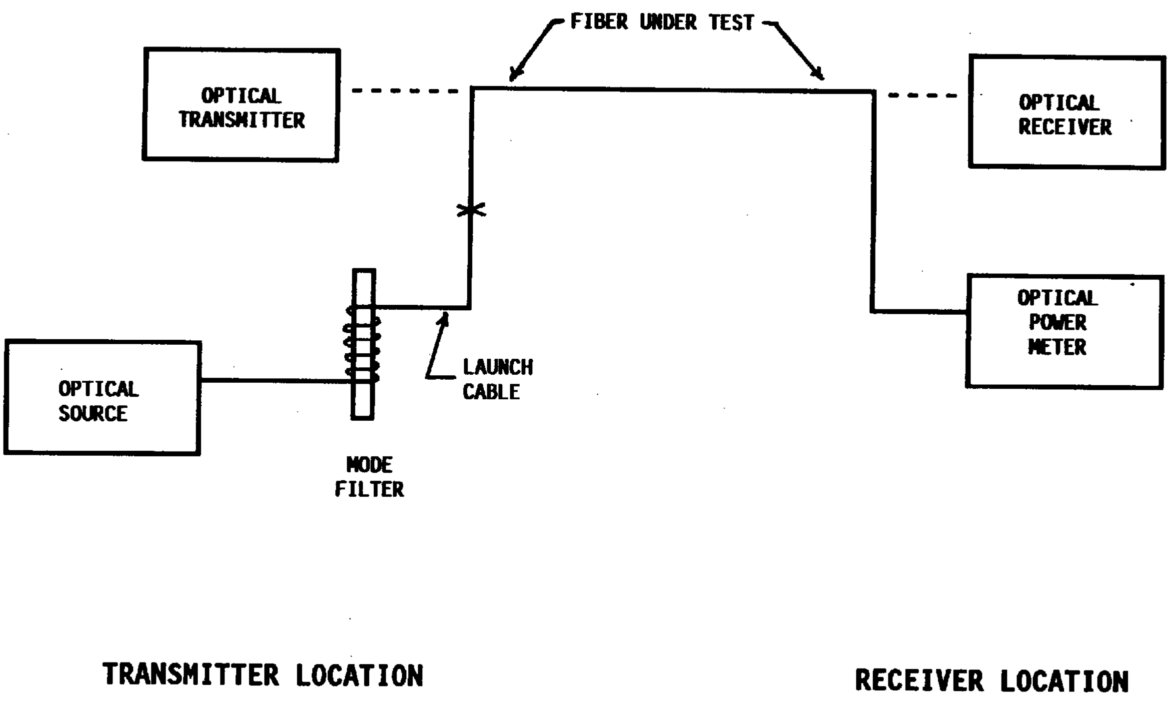


Figure 5-2. Cable Loss Measurement Test Setup

in step (8). The difference is the loss of the cable under test.

(13) Compare the loss measured with prescribed tolerances in chapter 3.

(14) Turn off the test equipment and disconnect the launch cable from the fiber under test. Clean the connector of the fiber under test using alcohol and lint free cloth, and reconnect the fiber to the optical transmitter. Disconnect the fiber under test from the power meter, clean its connector, and reconnect it to the optical receiver.

(15) Verify that system is operating normally.

118. CABLE PERFORMANCE USING OTDR.

a. Object. This procedure is used to check the quality of the optical fiber run from the transmitter to the receiver. The test will detect any degradation that may have occurred in the fiber, splices, and connectors.

b. Discussion. An OTDR is used to provide a graphical picture of the cable run. This is done by launching a pulse of light down the fiber in the same direction as it is normally used (locate the OTDR at the transmit end of the fiber) and analyzing the light reflected back into the OTDR from the fiber. Using the OTDR, all features (splices, connectors, breaks) of the cable are located. The loss and reflection of each splice and connector are measured. New features are identified and quantified for loss. The overall cable loss is measured. Data gathered from this OTDR measurement is compared to the most previous OTDR run to detect degradations and identify any corrective actions needed.

c. **Test Equipment Required.** OTDR suitable for use on the cable to be tested. Suitability is determined as follows.

(1) The light source of the OTDR should be at the same wavelength as the optical transmitter normally used on the cable.

(2) OTDR's are specified for use on either single-mode or multimode fibers.

(3) The OTDR must have sufficient dynamic range to cover the attenuation of the fiber being tested.

d. **Detailed Procedure.**

(1) Place service on a backup fiber or coordinate a system outage with air traffic personnel.

(2) Clean all connectors prior to testing with alcohol and lint-free pads, or with treated pads made for the purpose.

(3) Turn off the optical transmitter and disconnect the fiber-optic cable to be tested. If possible, connect the cable to the OPTICAL OUTPUT connector of the OTDR. If this is not possible due to distance or connector incompatibility, use the optical interface cable provided with the OTDR and adapters as required. Refer to figure 5-3.

(4) Set OTDR controls to view the entire fiber. Manufacturer's instruction books should be consulted for functions of specific controls, however the following general guidance is offered.

(a) Use the horizontal position control to adjust the position of the display left-to-right.

(b) Use the vertical position control to adjust the position of the display up or down.

(c) Use the "dB/div" control to expand or compress the vertical scale of the display. This control should be set to allow the graph to fill the display vertically.

(d) Use the "dist/div" (distance per division) control to expand or compress the horizontal scale of the display. This control should be set to display the entire length of the cable.

(5) If OTDR is capable, make a printout of the graph. Label the printout with the following information and retain with the site records.

(a) Date and time.

(b) Fiber identification number.

(c) Fiber type.

(d) OTDR location.

(e) OTDR settings (dB/div, dist/div, filter, pulse width, etc.).

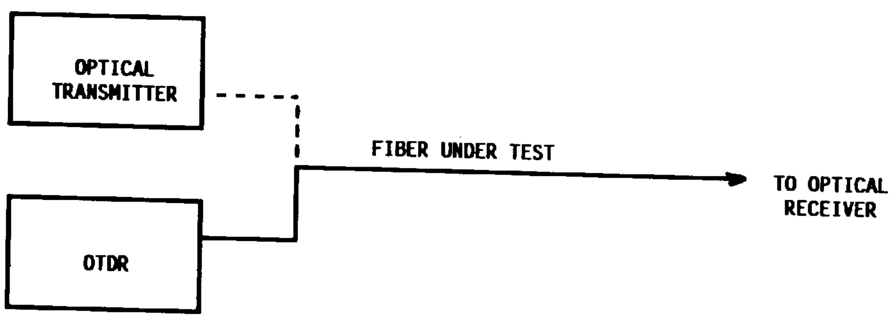


Figure 5-3. Cable Performance Test Setup

(6) Identify all features found in the cable run. A feature is any anomaly that causes the graph to deviate from the normal backscatter signal level. Record the following information for each feature. OTDR settings may be adjusted to zoom in on the feature for greater resolution.

(a) Location (distance from the OTDR).

(b) Reflection amount.

(c) Loss (using least-squares approximation method).

(7) Measure and record the overall loss of the cable and the total distance of the cable run.

(8) Compare all data to that taken in the most previous OTDR run and resolve any differences. When all differences have been resolved, discard data from previous OTDR run. Retain all new data and graphs with site records.

(9) Turn off the OTDR and disconnect the fiber under test. Clean the fiber under test connector and reconnect the fiber to the optical transmitter.

(10) Turn on the optical transmitter and verify that system is operating normally.

119. OPERATIONAL CHECKOUT OF SPARE DEVICES AND CABLES.

a. Objective. This procedure checks out all backup devices and cables to ensure that they are operational and able to carry the traffic should a primary unit fail. It also checks out automatic fault sensing and switching circuitry to ensure that backup devices are put online.

b. Discussion.

(1) Spare devices and cables are often provided in the National Airspace System (NAS) to backup critical traffic should a primary device fail. Normally, redundancy is limited to equipment items that affect a large number of channels. These items include fiber-optic cables, optical transceivers, and power supplies. Two runs of fiber-optic cabling will normally be installed between two locations. Each run will use a different route to avoid both cables being damaged in one incident, and each cable will interface with an optical transceiver to form a redundant optical link. Spare links may be switched into operation automatically on command by a monitoring system, or may be manually patched in by a technician to restore service. As there is an even chance that a spare device will fail before the primary, and online monitoring systems do not always detect failure of a spare, operation of the spare must be checked periodically.

(2) In some instances, it is possible that redundancy is carried down to the circuit level, and that a backup multiplexer is installed and dedicated to a backup fiber-optic link. Restoral in these cases is usually performed manually, with individual channels of the multiplexer being patched.

c. Test Equipment Required. None.

d. Detailed Procedure.

(1) Due to the risk of putting spare equipment into operational service, this test should be performed during nonpeak traffic hours. Testing should be coordinated with air traffic personnel as service interruptions may occur during patching of spare devices.

(2) Redundant Optical Cables and Transceivers. In most instances where backup cables and transceivers are provided, a monitoring system that senses a failure will provide automatic switching between the main and standby units. This capability exists on links using the Unimux 832, Rockwell DML-45, PCO Model 5000R, and the Larus FT-2 fiber-optics equipment. On other links, manual patching at the electrical interface of the optical transceiver may be used for a restoral. In still other cases, the primary and backup optical links may each be dedicated to individual multiplexers, thereby extending redundancy down to the individual circuit level.

(a) Redundant Optical Links With Automatic Switching.

1 Using front panel indicators, ascertain that no faults are apparent on the backup fiber-optic link.

2 At the back of the unit, or at an optical

patch panel when provided, disconnect the receive fiber-optic cable from the online transceiver.

3 Observe that the front panel of the transceiver shelf indicates that the backup transceiver is online. Observe that multiplexing equipment associated with the fiber-optic link is indicating the receipt of good data.

4 Verify with user personnel that at least one of the circuits being sent over the link is operating normally.

5 Leave the equipment in this condition for a minimum of 15 minutes.

6 Clean optical connector previously removed with alcohol and lint-free pad and reconnect.

7 Verify normal system operation. Note that the backup unit may stay online in some equipment configurations.

(b) Redundant Optical Links With Manual Patching.

1 Using front panel indicators, ascertain that no faults are apparent on the backup fiber-optic link.

2 Patch the electrical output of the backup optical transceiver to the operational equipment.

3 If applicable, observe that multiplexing equipment associated with the fiber-optic link is indicating the receipt of good data.

4 Verify with user personnel that at least one of the circuits being sent over the link is operating normally.

5 Leave the equipment in this condition for a minimum of 15 minutes.

6 Remove patch. Verify normal system operation.

(c) Redundant Optical Links With Redundant Multiplexers. For purposes of this procedure, it is assumed that automatic switching is not used on the channel outputs of redundant multiplexers. This procedure requires two individuals, one at each end of the link.

1 Observe the front panel of the redundant fiber-optic transceiver and ascertain that no faults are indicated.

2 Observe the front panel of the redundant multiplexer and ascertain that no faults are evident. Also, ascertain that it is receiving aggregate data from the fiber-optic link.

3 Identify each circuit to be patched and coordinate check with the user of that circuit.

4 Manually patch in the backup circuit at both ends and verify circuit operation with user personnel.

5 Repeat step 4 until all redundant circuits have been patched in to the user.

6 Leave patches in for a minimum of 15 minutes.

7 Remove patches and verify operation of circuits.

120. OPTICAL POWER AT RECEIVER.

a. Object. This procedure measures the optical power at the receiver. In this way, degradation in both the optical transmitter and cable will be detected.

b. Discussion.

(1) Sufficient optical power must be provided to the receiver for it to produce a usable electrical signal output.

(2) An optical power meter is used to measure the average power level present at the receiver input. In many cases the modulating signal will not affect the average power level read on the meter. Most data links use coding techniques that result in a 'one' being transmitted half the time, making for a consistent average power level. Other links will require that a controlled modulating signal be used during the measurement to obtain repeatable results. Data links used directly with RS-232, RS-422, or bipolar signals will require replacing

the normal data input with a square wave generator or bit error rate test set. Video links require the injection of a sine wave to ensure that a steady, repeatable average power level is measured.

c. **Test Equipment Required.**

(1) Square Wave Generator or Bit Error Rate (BER) Tester. BER tester must be capable of providing an alternating "1-0" pattern in the format used.

(2) Sine Wave Generator.

(3) Optical Power Meter.

d. **Detailed Test Procedure.**

(1) Place service on a backup link or coordinate a system outage with air traffic.

(2) Clean all connectors prior to testing with alcohol and lint-free pads, or with treated pads made for the purpose.

* (3) Data Link (Alcatel SONET, Racal PremNet 5000, Larus FO-1006, Larus FT2-0, Unimux 832, Rockwell DML-45, AT&T FT-1, PCO-5000R Intcm/Data Channel). Refer to figure 5-4 for test setup. *

(a) Note whether or not the optical transmitter uses a laser light source. Observe precautions when working with laser light sources.

(b) Set power meter wavelength calibration to correspond to the wavelength of the optical transmitter. Zero the power meter in accordance with manufacturer's instructions.

(c) Disconnect the optical fiber from the receiver of the link under test. Connect this fiber to the optical power meter, using adapters as required.

(d) Read and record the received power level.

(e) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical transmitter.

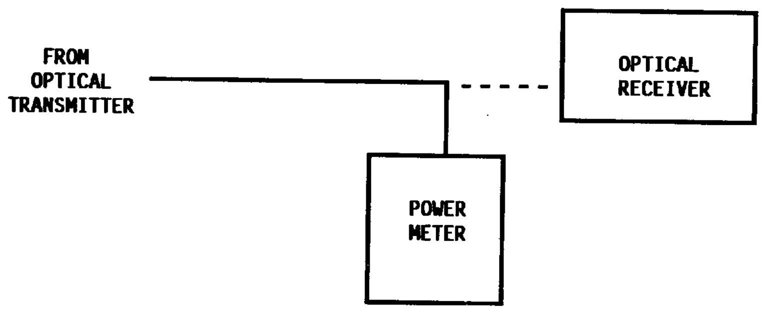


Figure 5-4. Receive Optical Power Test Setup Using Normal Modulation Source

(f) Verify normal system operation.

(4) Data Link (Math Associates XD-1000, RD-1000, TTL Version). Performance of this procedure requires two individuals, one located at the transmitter and one at the receiver. Refer to figure 5-5 for test setup.

(a) At the transmitter location, disconnect the normal modulating signal from input to the XD-1000. Set up a square wave generator (or BER tester) to provide a 10-kHz, 50-percent duty cycle signal varying between 0 V and +5 V, and connect its output to the XD-1000.

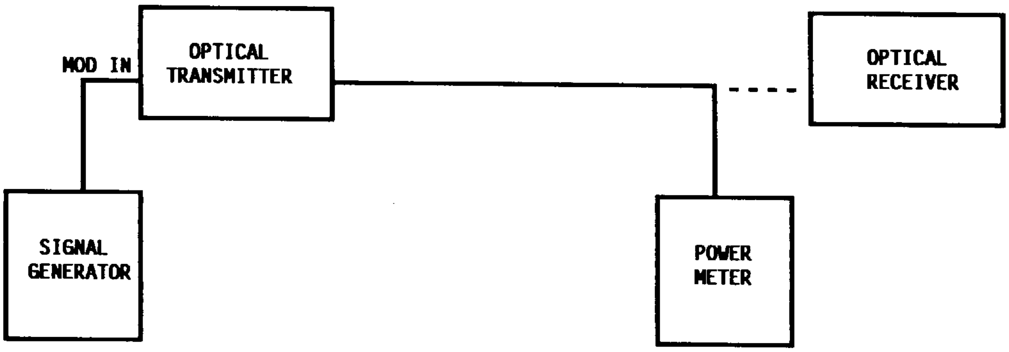


Figure 5-5. Receive Optical Power Test Setup Using Test Modulation Source

(b) At the receiver location, set the power meter wavelength calibration for 820 nm, and zero the power meter. Disconnect the optical fiber from the receiver under test, and connect the fiber to the optical power meter, using adapters as required.

(c) Read and record the received power level.

(d) Disconnect the cable from the power meter. Clean connectors using alcohol and lint-free pads, and reconnect the cable to the optical transmitter.

(e) At the transmitter location, reconnect the normal modulating signal to the XD-1000.

(f) Verify normal system operation.

(5) Video Link (Math Associates XV-1500, RV-1500). Performance of this procedure requires two individuals, one located at the transmitter and one at the receiver. Refer to figure 5-5 for test setup.

(a) At the transmitter location, disconnect the normal modulating signal from the input to the XV-1500. Set up a sine wave generator to provide a 100-kHz, 1-volt peak-to-peak signal across the input to the XV-1500. Note that the XV-1500 input impedance is 75 ohms.

(b) At the receiver location, set the power meter wavelength calibration for 820 nm, and zero the power meter. Disconnect the optical fiber from the receiver under test, and connect the fiber to the optical power meter, using adapters as required.

(c) Read and record the received power level.

(d) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver.

(e) At the transmitter location, reconnect the normal modulating signal to the XV-1500.

(f) Verify normal system operation.

(6) Video Link (PCO-5000R). The video portion of the PCO-5000R consists of six fiber-optic links to provide a redundant path for normal (NML) video, moving target indicator (MTI) video, and beacon (BCN) video. The BCN video circuit additionally carries azimuth change pulse (ACP) and azimuth reference pulse (ARP) signals. The fiber-optic transmitters and receivers used in the PCO-5000R are modified versions of the standard PCO-5000 units. This test will require two individuals to perform; one at the transmitter location

and one at the receiver. Refer to figure 5-5 for test setup.

(a) At the receiver location, select channel 2 for use on the NML video switch module.

(b) At the transmitter location, disconnect the NML video input from J1-1 of chassis 1. Set up a sine wave generator to provide a 100-kHz, 1-volt peak-to-peak signal and connect output to J1-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Increase the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(c) At the receiver location, set the power meter wavelength calibration for 1300 nm, and zero the power meter. Disconnect the optical fiber from the NML video channel 1 receiver (FJ11 of chassis 1), and connect the fiber to the optical power meter using adapters as required.

(d) Read and record the received power level.

(e) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ11.

(f) At the transmitter location, disconnect the signal generator and reconnect the normal modulating signal to J1-1. Do not readjust the signal generator level.

(g) Verify normal system operation.

(h) At the receiver location, select channel 1 for use on the NML video switch module.

(i) At the transmitter location, disconnect the NML video input from J2-1 of chassis 1. Connect output of signal generator to J2-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Adjust the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(j) At the receiver location, set the power meter wavelength calibration for 1300 nm, and zero the power meter. Disconnect the optical fiber from the NML video channel 2 receiver (FJ31 of chassis 1), and connect the fiber to the optical power meter using adapters as required.

(k) Read and record the received power level.

(l) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ31.

(m) At the transmitter location, disconnect the signal generator and reconnect the normal modulating signal to J2-1. Do not readjust the signal generator level.

(n) Verify normal system operation.

(o) At the receiver location, select channel 2 for use on the MTI video switch module.

(p) At the transmitter location, disconnect the MTI video input from J1-1 of chassis 2. Connect output of signal generator to J1-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Adjust the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(q) At the receiver location, set the power meter wavelength calibration for 1300 nm, and zero the power meter. Disconnect the optical fiber from the MTI video channel 1 receiver (FJ41 of chassis 1), and connect the fiber to the optical power meter using adapters as required.

(r) Read and record the received power level.

(s) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ41.

(t) At the transmitter location, disconnect the signal generator, and reconnect the normal modulating signal to J1-1. Do not readjust the signal generator level.

(u) Verify normal system operation.

(v) At the receiver location, select channel 1 for use on the NML video switch module.

(w) At the transmitter location, disconnect the MTI video input from J2-1 of chassis 2. Connect output of signal generator to J2-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Adjust the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(x) At the receiver location, set the power meter wavelength calibration for 1300 nm, and zero the power meter. Disconnect the optical fiber from the MTI video channel 2 receiver (FJ61 of chassis 1), and connect the fiber to the optical power meter using adapters as required.

(y) Read and record the received power level.

(z) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ61.

(aa) At the transmitter location, disconnect the signal generator and reconnect the normal modulating signal to J2-1. Do not readjust the signal generator level.

(ab) Verify normal system operation.

(ac) At the receiver location, select channel 2 for use on the BCN & DATA video switch module.

(ad) At the transmitter location, disconnect the BCN video input from J3-1 of chassis 1. Connect output of signal generator to J3-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Adjust the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(ae) At the receiver location, set the power meter wavelength calibration for 1300 nm, and zero the power meter. Disconnect the optical fiber from the BCN video channel 1 receiver (FJ11 of chassis 2), and connect the fiber to the optical power meter, using adapters as required.

(af) Read and record the received power level.

(ag) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ11.

(ah) At the transmitter location, disconnect the signal generator and reconnect the normal modulating signal to J3-1. Do not readjust the signal generator level.

(ai) Verify normal system operation.

(aj) At the receiver location, select channel 1 for use on the BCN & DATA video switch module.

(ak) At the transmitter location, disconnect the BCN video input from J5-1 of chassis 1. Connect output of signal generator to J5-1. Using an oscilloscope, measure voltage at the MONITOR port on the front panel of the transmit module. Adjust the signal generator output until 1 volt peak-to-peak is seen on the oscilloscope.

(al) At the receiver location, set the power meter wavelength calibration for 1300 nm and zero the power meter. Disconnect the optical fiber from the BCN video channel 2 receiver (FJ41 of chassis 2), and connect the fiber to the optical power meter, using adapters as required.

(am) Read and record the received power level.

(an) Disconnect the cable from the power meter. Clean connectors, using alcohol and lint-free pads, and reconnect the cable to the optical receiver FJ41.

(ao) At the transmitter location, disconnect the signal generator and reconnect the normal modulating signal to J5-1. Do not readjust the signal generator level.

(ap) Verify normal system operation.

121. VOICE CHANNEL CHECKS.

a. Objective. This procedure checks the quality of voice channels provided by the fiber-optic link to ensure that degradation has not occurred.

b. Discussion.

(1) Some fiber-optics equipment includes integral multiplexing equipment, and as such, provides an electri-

cal interface to the user consisting of individual voice and data channels. In these cases a check of the fiber-optic equipment must include a check of the individual channels provided by that equipment.

(2) Testing of voice channels is not performed on a fiber link-by-fiber link basis. In many instances, fiber transceivers are arranged in a ring configuration, with the endpoints of a voice channel located somewhere on the ring. A voice channel may therefore use more than one fiber-optic link to get from one endpoint to the other, passing through intermediate transceivers. Testing of a voice channel will be conducted between endpoints, which are the locations it is dropped off to the user.

c. **Test Equipment Required.** Two each of either a transmission test set, TTS-44, or transmission impairment measurement system, HP-4935A.

d. **Detailed Procedure.**

(1) Preliminary.

(a) Coordinate a channel outage with air traffic personnel prior to conducting this test.

(b) Locate a TTS-44 or HP-4935A at either end of the voice channel. Performance of this procedure requires two individuals, one located at either end of the voice channel.

* (c) Set up the test equipment as shown in figure 5-6 or 5-6A. For purposes of this test, the sites are arbitrarily designated A and B. The test should be connected to the patch panel in a manner that breaks the connection with the user equipment. In the PremNet 5000 four-wire VF module, where a patch panel is not available, the VF modules may be accessed using the 4024E two-wire-to-four-wire repeaters as follows.

1 Insert dummy plugs in the 4W RCV IN and 4W XMT OUT jacks located on the front of the 4024E repeater of the channel under test. Refer to figure 5-6A. This isolates the 4024E from the circuit. *

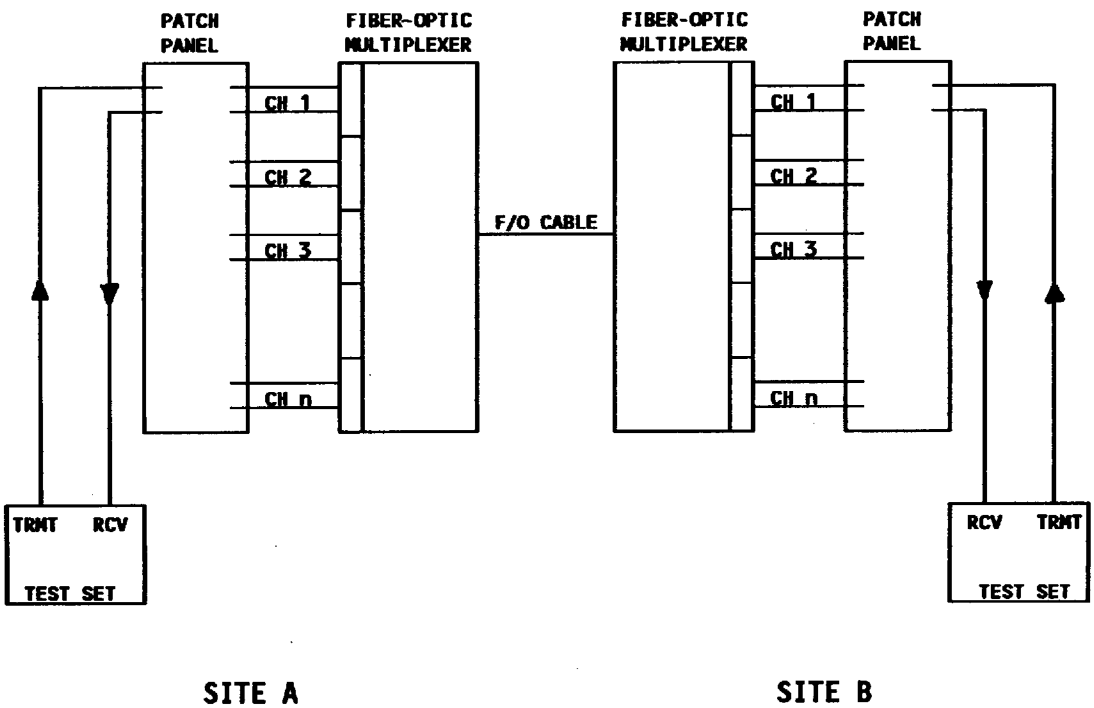
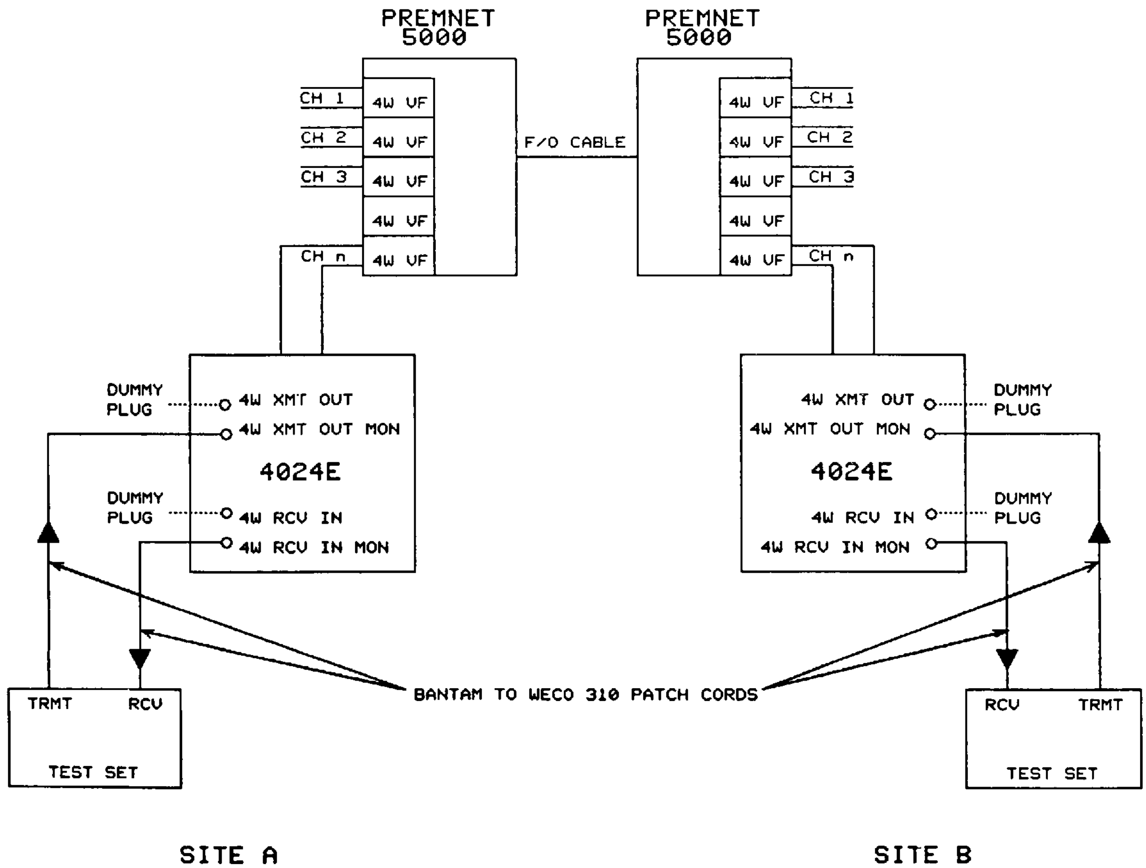


Figure 5-6. Voice Channel Checks Test Setup

*



*

Figure 5-6A. Voice Channel Check of PremNet Four-Wire VF Module

* 2 Connect a WECO 310-to-bantam patch cord from the TRMT jack of the test equipment to the 4W XMT OUT MON jack of the 4024E.

3 Connect another WECO 310-to-bantam patch cord from the RCV jack of the test equipment to the 4W XMT OUT MON jack of the 4024E. *

(d) The following procedures are written for use with the HP4935A. However, there is enough commonality between the HP4935A and the TTS-44 that the procedure should easily accommodate the TTS-44.

(2) 1004 Hz Loss

(a) Set up the HP4935A at sites A and B as follows.

1 Press DISPLAY key to light TRMT.

2 Set MEAS key to light LEVEL FREQUENCY.

3 Configure SET UP keys for 600 ohms.

4 Press F2 key to set frequency to 1004 Hz.

5 Adjust OUTPUT LEVEL to read 0 dBm.

(b) At site A, press DISPLAY key to light RCV. Read and record the receive signal level at site A.

(c) At site B, press DISPLAY key to light RCV. Read and record the receive signal level at site B.

(d) Compare loss in each direction with the standard listed in chapter 3.

(3) Frequency Response.

(a) Repeat step (2), but set frequency to 404 Hz using the F1 key.

(b) Read and record receive levels at both sites as in steps 2(b) and 2(c).

(c) Repeat step 2(a) above, but set frequency to 2804 Hz using the F3 key.

(d) Read and record receive levels at both sites as in steps 2(b) and 2(c).

(e) Compare receive levels for 404 Hz and 2804 Hz with 1004 Hz level measured previously. Ensure that the difference does not exceed the tolerance in chapter 3.

(4) Idle Noise.

(a) Set up the HP4935A at both sites A and B as follows.

1 Press DISPLAY key to light TRMT.

2 Set MEAS key to light NOISE.

3 Configure SET UP keys for 600 ohms.

(b) At site A press DISPLAY key to light RCV. Press FILTER key to select C-MESSAGE. Read and record the dBrnC noise level in the display.

(c) Repeat step (4)(b) at site B.

(d) Compare noise levels measured to standards in chapter 3.

122. BIT ERROR RATE TESTING.

a. Object. This procedure verifies the capability of channels to transmit and receive data without errors.

b. Discussion.

(1) This testing is performed on unused data channels to ensure they are ready for use when needed. Data channels that are in use are not tested. If the data channel is providing good service to the user it should not be taken out of service for performance testing.

(2) By necessity, bit error rate testing on low data rate channels is qualitative rather than quantitative. That is, it checks that the channel will pass data for a limited period of time with no errors rather than verifying that the channel passes data with a bit error rate less than 10^{-9}, the typical performance standard. This is due to the fact that 10^{10} bits must be passed to statistically state that a bit error rate of 10^{-9} has been obtained. On a 19.2 kbps data channel, it would take approximately six days of testing to verify a bit error rate of 10^{-9}.

(3) The primary method of testing should connect a bit error rate (BER) tester at each end of the data channel. Refer to figure 5-7. Data is transmitted in both directions between the two BER testers. Bit errors would show up on one or both channels, depending on whether a problem affects the entire channel or only one half (direction) of the channel.

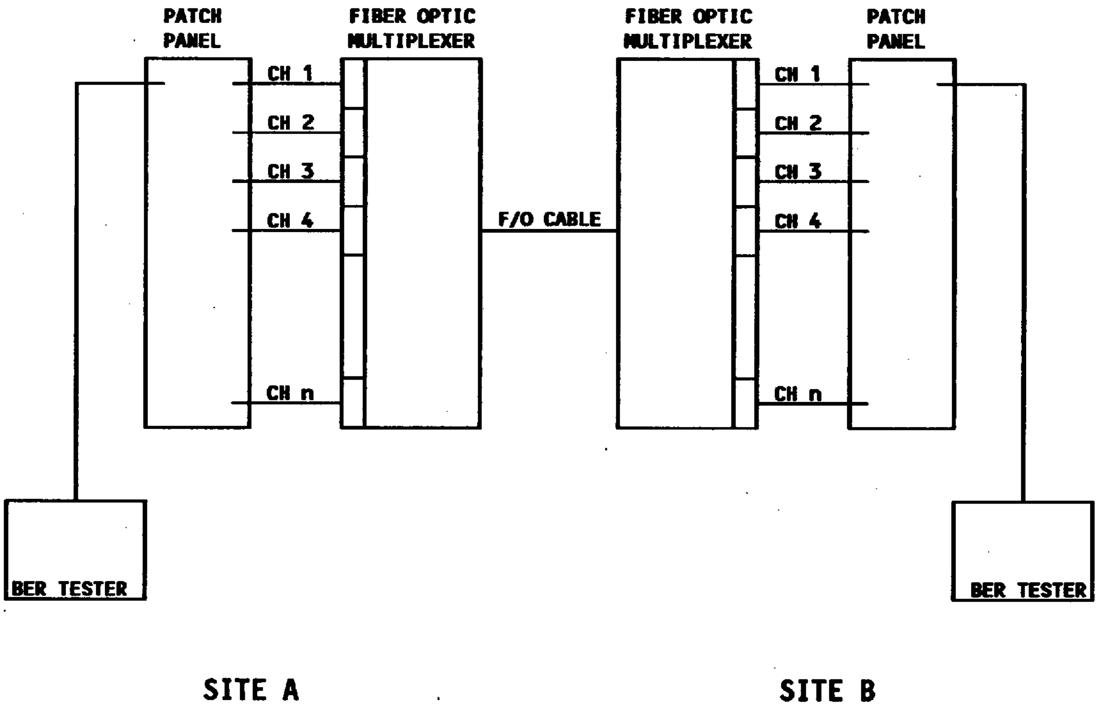


Figure 5-7. Bit Error Rate Test Setup (Primary)

(4) An alternative method of testing may be used when only one BER tester is available. Refer to figure 5-8. This method connects a BER tester to one end of the data channel and uses a crossover plug at the other end to loop the data back to the BER tester. A bit generated by the BER tester is sent through the data channel to the distant end. At the distant end, a cross-over plug is connected to the output of the patch panel. This plug takes the received data bit and connects it to the transmit data port for retransmission back to the BER tester.

c. **Test Equipment Required.** Two BER testers are required to test a data channel. Alternatively, one BER tester and one data crossover cable for loopback could be used where two BER testers are not available.

d. **Detailed Procedure.**

(1) Set up test equipment as shown in figures 5-7 or 5-8, depending on whether two BER testers are used or only one.

(2) Specific instructions on settings for the BER tester will not be provided due to the many types of testers available. Settings will also depend on how the data channel cards are strapped.

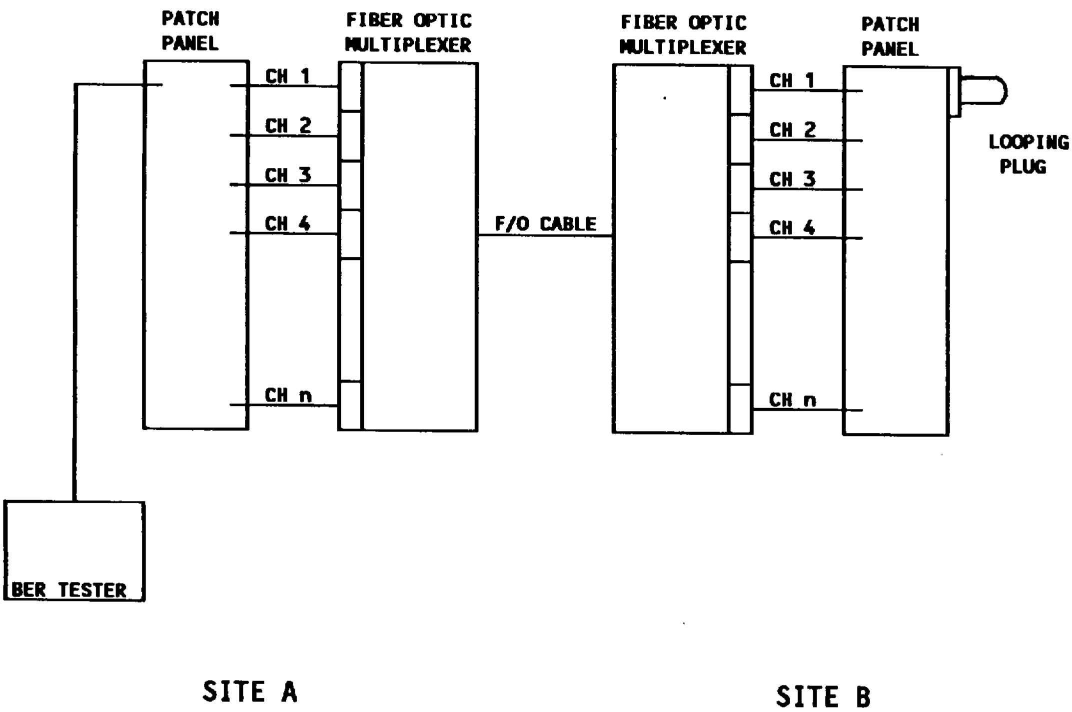


Figure 5-8. Bit Error Rate Test Setup (Alternate)

(3) In general, the technician must ensure that the channel cards at both ends of the data channel are strapped to allow them to operate with each other. Pay particular attention to timing sources, making sure that all items are synchronized to the same clock source. Set channel cards and BER testers to the same data speed.

(4) Set up the BER tester(s) to transmit the 511 bit pattern. Monitor the BER testers for errors for a period of 15 minutes. The test is considered successful if no errors are noted in a 15-minute period.

123. VIDEO GAIN AND BANDWIDTH OF PCO-5000R.

a. Object. This procedure verifies that the PCO-5000R radar remoting system provides sufficient bandwidth and unity gain for the radar signals.

b. Discussion.

(1) The PCO-5000R is a fiber-optic link system that provides for transmission of radar video, control, and azimuth information between the radar site and the

indicator site. The fiber-optic links are intended to be transparent to system operation. Ideally, the signal entering the link would be identically reproduced at the output.

(2) Verification of bandwidth and unity gain will be performed by injecting discrete signals into the transmitter and measuring the output of the receiver. The difference between the signals is the gain of the link and the difference between measured outputs establishes the bandwidth.

c. Test Equipment Required. Signal generator HP3336A and selective level meter HP3586A, or equal.

d. Detailed Procedure.

(1) Refer to figure 5-9 for a layout of the PCO-5000R showing connector designations. This test should not result in any loss of service. This test requires two individuals to perform, one at the transmitter location and one at the receiver.

(2) At the receive location, select channel 2 for service using the MANUAL CH SEL button on the NML video switch module.

(3) At the transmit location, set up the signal generator as follows.

Output Impedance: 75 ohms
Level: -10 dBm
Frequency: 100 Hz

(4) Disconnect the cable from J1-1 of transmit chassis 1. Connect the output of the signal generator to J1-1.

(5) At the receiver site, set the selective level meter as follows.

Input Impedance: 75 ohms
Measurement Mode: LO DIST
Bandwidth: 20 Hz
Frequency: 100 Hz

(6) Disconnect the cable from connector J1-1 of receive chassis 1. Connect the input of the selective level meter to J1-1, and read the power indicated on the selective level meter.

(7) At the transmit and receive locations, set the signal generator and selective level meter for the following frequencies. Read the power on the selective level meter for each of the frequencies.

1 kHz
10 kHz
100 kHz
500 kHz
1 MHz
5 MHz
10 MHz
12 MHz

(8) Compare all power readings to the input power level of -10 dBm. Power readings should not deviate from the -10 dBm by more than the tolerance specified in chapter 3.

(9) Note the highest and lowest power readings. The difference between them should not exceed 3 dB.

(10) Disconnect test equipment and reconnect video cables to transmit and receive chassis.

(11) At the receive location, select channel 1 for service using the MANUAL CH SEL button on the NML video switch module.

(12) Repeat the procedure in steps (3) through (9) for NML video channel 2. Connect signal generator to J2-1 of transmit chassis 1 and the selective level meter to J3-2 of receive chassis 1.

(13) At the receive location, select channel 2 for service using the MANUAL CH SEL button on the MTI video switch module.

(14) Repeat the procedure in steps (3) through (9) for MTI video channel 1. Connect the signal generator

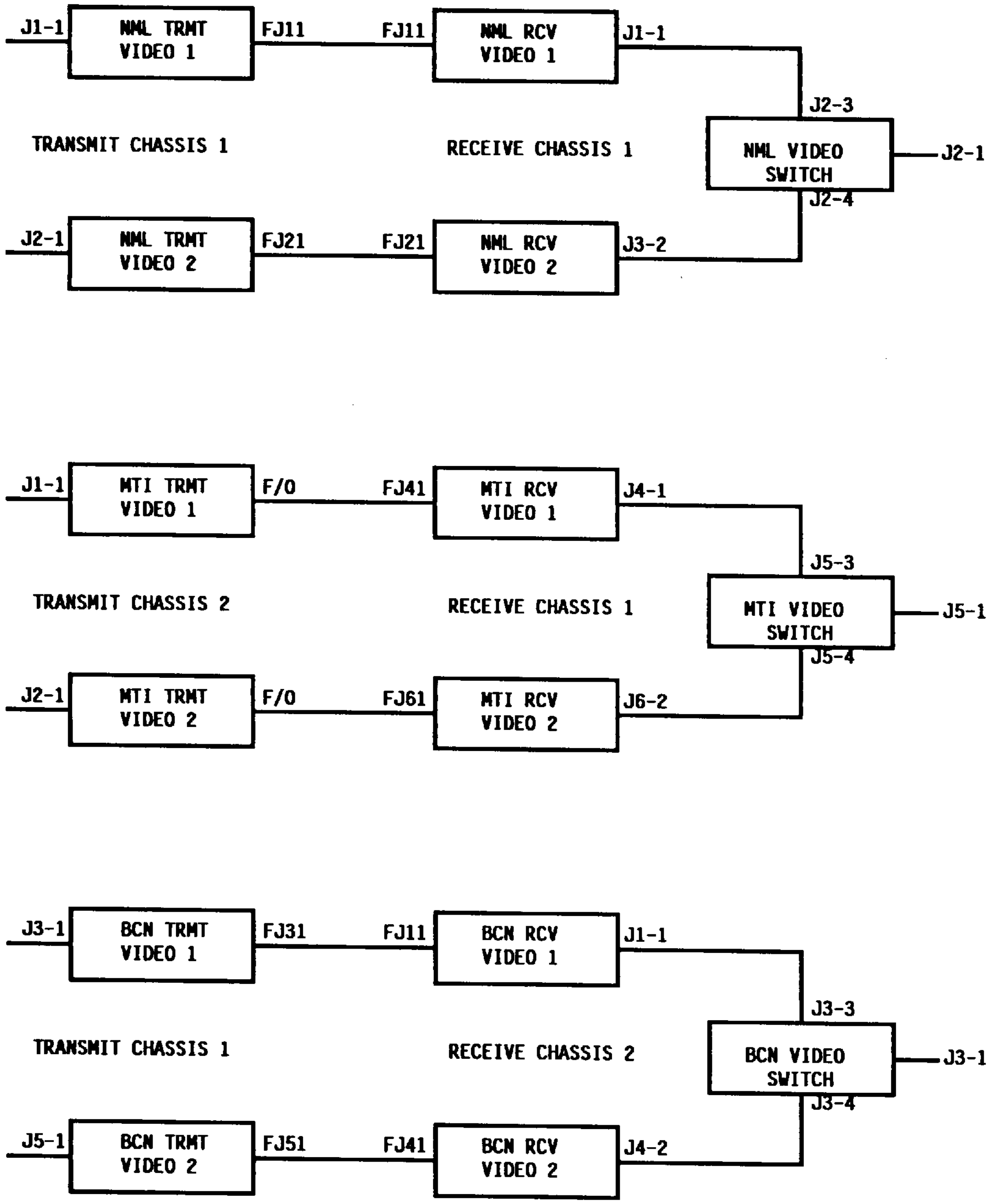


Figure 5-9. PCO-5000R Video Paths

to J1-1 of transmit chassis 2 and the selective level meter to J4-1 of receive chassis 1.

(15) At the receive location, select channel 1 for service using the MANUAL CH SEL button on the MTI video switch module.

(16) Repeat the procedure in steps (3) through (9) for MTI video channel 2. Connect the signal generator to J2-1 of transmit chassis 2 and the selective level meter to J6-2 of receive chassis 1.

(17) At the receive location, select channel 2 for service using the MANUAL CH SEL button on the BCN video switch module.

(18) Repeat the procedure in steps (3) through (9) for BCN video channel 1. Connect the signal generator to J3-1 of transmit chassis 1 and the selective level meter to J1-1 of receive chassis 2.

(19) At the receive location, select channel 1 for service using the MANUAL CH SEL button on the BCN video switch module.

(20) Repeat the procedure in steps (3) through (9) for BCN video channel 2. Connect the signal generator to J5-1 of transmit chassis 1 and the selective level meter to J4-2 of receive chassis 2.

124. VIDEO BANDWIDTH OF MATH ASSOCIATES XV-1500, RV-1500.

a. Object. This procedure verifies that the fiber-optic link provided by the XV-1500 transmitter and RV-1500 receiver have sufficient bandwidth to pass a video signal.

b. Discussion. Verification of bandwidth will be performed by injecting discrete signals into the transmitter and measuring the output of the receiver. The difference between measured outputs establishes the bandwidth of the link.

c. Test Equipment Required. Signal generator HP3336A and selective level meter HP3586A, or equal.

d. Detailed Procedure.

(1) Place service on a backup link or coordinate a system outage with air traffic personnel. Performance of this test requires two individuals, one at the transmitter location and one at the receiver. Refer to figure 5-10 for test setup.

(2) At the transmit location, set up the signal generator as follows.

Output Impedance: 75 ohms
Level: -10 dBm
Frequency: 100 Hz

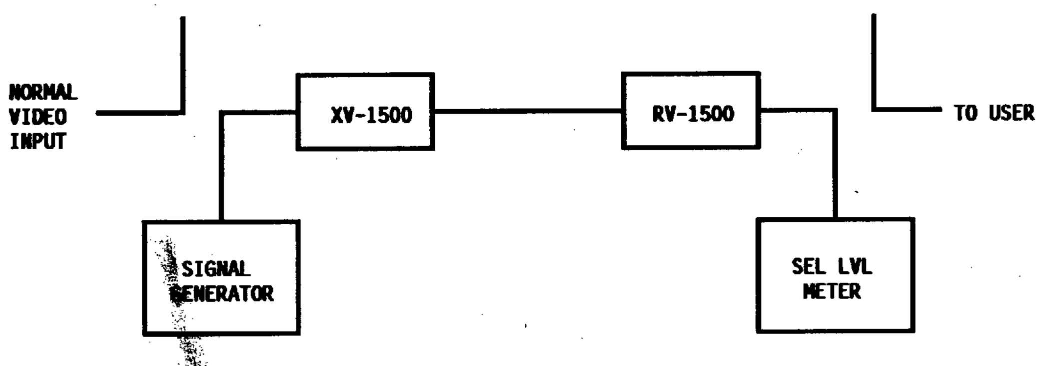


Figure 5-10. Math Associates XV-1500, RV-1500, Video Bandwidth Test Setup

(3) Disconnect cable from the input to the XV-1500. Connect output of the signal generator to the XV-1500.

(4) At the receiver site, set selective level meter as follows.

Input Impedance: 75 ohms
Measurement Mode: LO DIST
Bandwidth: 20 Hz
Frequency: 100 Hz

(5) Disconnect cable from the output of the RV-1500. Connect input of selective level meter to the RV-1500 output, and read the power indicated on the selective level meter.

(6) At the transmit and receive locations, set the signal generator and selective level meter for the following frequencies. Read the power on the selective level meter for each of the frequencies.

1 kHz
10 kHz
100 kHz
500 kHz
1 MHz
5 MHz
10 MHz

(7) Note the highest and lowest power readings. The difference between them should not exceed 3 dB.

(8) Disconnect test equipment and reconnect video cables to transmit and receive chassis.

(9) Verify normal system operation.

125. SYSTEM GAIN OF MATH ASSOCIATES XV-1500, RV-1500.

a. Object. This procedure measures the gain of the fiber-optic link provided by the XV-1500 transmitter and RV-1500 receiver.

b. Discussion. Verification of gain will be performed by injecting a discrete signal into the transmitter and measuring the output of the receiver. The difference between the signal injected and the signal measured is the gain of the link.

c. Test Equipment Required. Signal generator and oscilloscope.

d. Detailed Procedure.

(1) Place service on a backup link or coordinate a system outage with air traffic personnel. Performance of this test requires two individuals, one at the transmitter location and one at the receiver. Refer to figure 5-11 for test setup.

(2) At the transmit location, disconnect the video input from the XV-1500 transmitter.

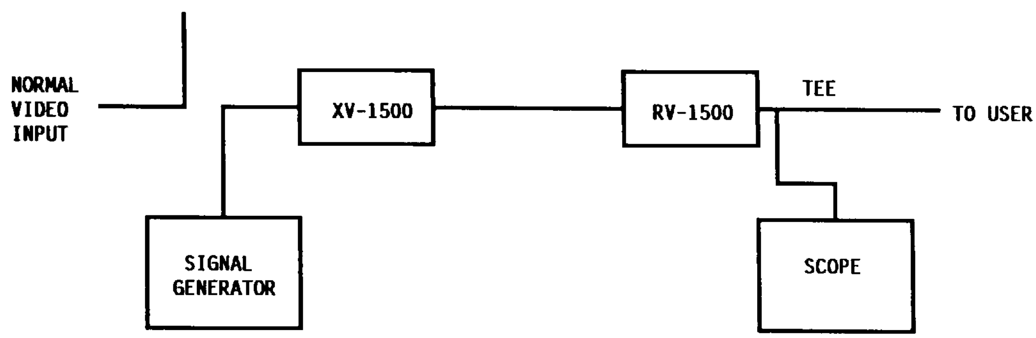


Figure 5-11. Math Associates XV-1500, RV-1500, System Gain Test Setup

(3) Connect a signal generator to the XV-1500 and set up the signal generator to provide a 100-kHz sine wave of 1 volt peak-to-peak.

(4) At the receive location, disconnect the video output cable from the RV-1500 receiver. Install a BNC tee adapter on the output of the RV-1500 and reconnect the video output cable. Connect an oscilloscope to the open leg of the tee adapter. (The output cable is left connected to terminate the output in 75 ohms impedance.)

(5) Measure and record the signal on the oscilloscope in volts peak-to-peak.

* **126. VISUAL CHECK.**

a. Object. This procedure verifies that the display LED's on the front panel of each node indicate proper operation.

b. Discussion. Each individual module has LED's that indicate specific conditions. Refer to the appropriate equipment manual for the meaning of each LED.

c. Test Equipment. None

d. Detailed Procedure.

(1) PremNet 5000.

* (a) View the front panel. If access to all the nodes is not possible or practical, at least check the LED's at the master node.

(b) Ensure that primary link modules are active. A switchover to the standby module may indicate a failure in the primary link.

(c) The red LED on the Network Management Module at the master node indicates either a network alarm or an alarm at the master node. If an alarm condition exists, use the master Node Command Menu to determine the problem. For information about accessing and using the Node Command Menu, refer to the System Installation and Configuration Manual.

(2) SONET TM-50/ADM-50.

(a) In addition to local indicators, the TM-50/ADM-50 also supports remote audible and visual alarm interface. Remote indication may be accomplished through an alarm panel or through a graphic-display system such as programmable logic controllers (PLC).

(b) View the indicators. If an alarm exists, access the system through an ASCII terminal connected to the local CRAFT RS-232 to determine the problem. Refer to the manual for commands and instructions.

* **127.-130. RESERVED.** *

Section 2. OTHER MAINTENANCE TASKS PROCEDURES

131. UNIMUX 832 RECEIVER SYNC ADJUSTMENT.

a. Object. This procedure adjusts the multiplexer receiver sync trimpot R206.

b. Discussion. The Unimux 832 contains a fiber-optic transceiver with an integral multiplex/demultiplex capability. Unimux 832 fiber-optic transceivers communicate at a data rate of 20 Mbps. Synchronizing the demultiplex function to the incoming data is critical to operation.

c. Test Equipment Required. Screwdriver.

d. Detailed Procedure.

(1) Coordinate a service outage with air traffic control personnel.

(2) Locate the access hole for the R206 adjustment. On Unimux 832's equipped for use with fiber optics this adjustment should always be in the upper right corner of the unit faceplate and labeled SYNC ADJ.

(3) Noting that R206 is a 20-turn trimpot, turn R206 fully counterclockwise (ccw). The FAULT LED should blink, indicating loss of sync.

(4) Turn R206 cw until the LED goes off.

(5) Continue turning R206 cw, counting the

number of turns until the LED lights again.

(6) Based on the number of turns counted, turn R206 ccw until it is set midway between the two fault conditions.

132. MATH ASSOCIATES RD-1000 RECEIVER ALIGNMENT.

a. Object. This procedure aligns the RD-1000 fiber-optic receiver to provide the proper data signal output.

b. Discussion.

(1) The RD-1000 contains one adjustment which sets the operating point of the unit. The proper operating point is determined by the optical power level received by the unit.

(2) Adjustment of the operating point is made by injecting a data signal into the XD-1000 transmitter and monitoring the electrical output of the RD-1000 with an oscilloscope. The RD-1000 is adjusted to provide a data signal with the best overall symmetry achievable.

c. Test Equipment Required. Square-wave generator and oscilloscope.

d. Detailed Procedure.

(1) Place service on a backup link or coordinate a system outage with air traffic personnel. This test requires two individuals to perform, one at the transmitter location and one at the receiver. Refer to figure 5-12 for the alignment setup.

(2) At the receiver location, disconnect the normal user cable from the RD-1000 electrical output. Connect a tee adapter to the RD-1000 output connector. Connect an oscilloscope to one side of the tee, and a load resistor simulating the normal data receiver input impedance on the other side.

*U.S. GOVERNMENT PRINTING OFFICE 1993-0-568-016/80068

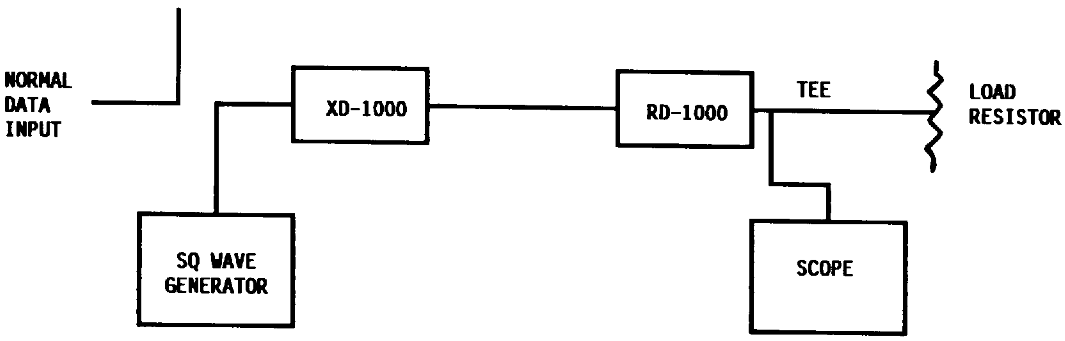


Figure 5-12. Math Associates RD-1000 Receiver Alignment Setup

(3) At the transmitter location, disconnect the normal modulating signal from input to the XD-1000. Set up a square-wave generator to provide a 10 kHz, 50 percent duty cycle signal varying between 0 V and +5 V, and connect its output to the XD-1000.

(4) At the receiver location, turn the adjustment control on the RD-1000 fully ccw, up to 30 turns. Then turn the adjustment control cw until the received signal appears on the oscilloscope. Slowly continue turning until a square wave with best overall symmetry is obtained.

(5) At the transmitter location, set the square-wave generator to provide a square wave with a frequency corresponding to the data rate normally used with the link. Apply this square wave with 50 percent duty cycle varying between 0 V and +5 V, to the XD-1000 transmitter.

(6) At the receiver location, fine tune the adjustment control again to obtain a square wave with the best overall symmetry.

(7) Disconnect test equipment and reconnect user cables.

(8) Verify normal system operation.

133.-140. RESERVED.

Section 3. SPECIAL MAINTENANCE PROCEDURES

141. POWER MARGIN DETERMINATION.

a. Object. This procedure provides a method of determining how much deterioration can occur in the transmitted optical power, the optical fiber attenuation, and the receiver sensitivity, before service is affected.

b. Discussion.

(1) The difference between the optical power coupled into a fiber from a transmitter and the optical power level required at the receiver for proper operation (receiver sensitivity) is known as the power budget. The

power budget, expressed in dB, represents the amount of loss that can occur between the transmitter and receiver before service is affected. These losses can take the form of the following.

(a) Degradation of optical power out of the transmitter light source.

(b) Degradation of the cable run between the transmitter and receiver, including all connectors and splices.

(c) Degradation of receiver sensitivity.

(2) The system designer uses the power budget to decide what type of fiber-optic cable should be used and whether a higher output power light source is required. A properly engineered link should not use up the entire power budget, however, to allow room for miscalculation and future added losses due to splices, connectors, etc.

(3) The difference between the power budget and the actual power at the receiver is known as the power margin. The power margin represents the amount of degradation that can occur in the optical link before service is affected. This figure would be of benefit for the maintainer of the link to know. NOTE: There is no hard and fast rule as to how large a power margin should be provided in a fiber-optic link. Information from the industry indicates that for a short link, such as that found in an airport loop, the power margin should be in the range of 3 to 6 dB.

(4) The power margin for a fiber-optic link is determined by inserting a variable optical attenuator between the transmitter and receiver. The attenuation is increased until the service provided is affected. Service would be affected on links providing data transmission when bit errors are seen. Service would be affected on links providing video transmission when the user judges the display presentation to be unusable.

c. Test Equipment Required. A variable optical attenuator and optical power meter are required for all links. Two bit error rate test sets are also required for data links.

d. Detailed Test Procedure.

(1) Place services served by the fiber-optic link under test on backup or coordinate an outage with air traffic personnel.

(2) Calibrate test setup.

(a) On data links, set up the BER testers on the highest data rate channel accessible. Set up testers to provide a random bit pattern. Ensure that timing and signal format are suitable for the channel by passing bits with no errors. Video links will be tested using the normal driving video signal.

(b) At the receiver location, disconnect the fiber-optic cable connector from the receiver, and connect it to an optical power meter. Read and record the power indicated on the power meter in dBm or dBu.

(c) Set up equipment for calibration as shown in figure 5-13. Note that the variable attenuator should be located at the receiver end of the fiber-optic cable run. Ensure that the variable attenuator is set to zero, and read the power level in dBm or dBu on the power

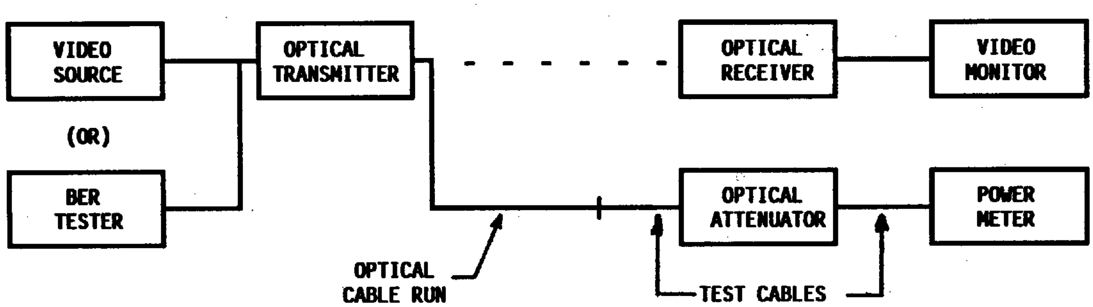


Figure 5-13. Power Margin Measurement Calibration Setup

meter. Subtract this power reading from that of step (b) to obtain the calibration factor. The calibration factor represents the insertion loss of the test cables and optical attenuator.

(3) Set up equipment as shown in figure 5-14.

(a) Digital Links.

1 Set up the BER tester at the receive location to display bit errors. Reset bit error count to zero. While monitoring the BER tester, slowly increase the optical attenuation until a bit error is seen. It is recommended that the attenuation be increased incrementally in 0.3 dB to 0.5 dB steps, and that the BER tester be monitored for approximately one minute following each increase.

2 When a bit error is recorded, set the BER tester to display bit error rate. After five minutes, note the bit error rate reading. Slowly increase or decrease the attenuation until a bit error rate reading between 1 x 10^{-6} and 5 x 10^{-6} is obtained. Note the attenuator reading in dB.

3 Add the attenuator reading noted above to the calibration factor determined previously. The total is the power margin.

4 Note that this represents the power margin for a BER threshold of 10^{-6}. While many digital links are specified to provide a maximum bit error rate of 10^{-9}, it is not practical to measure such a low bit error rate. Most data services will perform satisfactorily with a bit error rate of 10^{-6}.

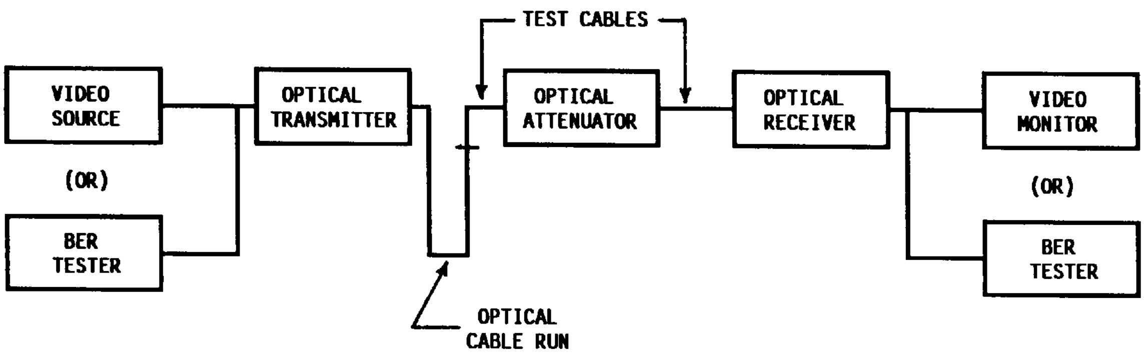


Figure 5-14. Power Margin Measurement Test Setup

(b) Video Links.

1 Determining the power margin of a video link requires a subjective evaluation that the video presentation is unusable. It is therefore advisable to have the actual user (air traffic control personnel) make this evaluation.

2 Slowly increase the optical attenuation until the video presentation is judged unusable. Note the attenuator reading in dB.

3 Add the attenuator reading noted above to the calibration factor determined previously. The total is the power margin.

142. CABLE FAULT ISOLATION.

a. Object. This procedure provides general guidance on ways to locate cable faults.

b. Discussion.

(1) A typical optical cable run consists of a cable containing many optical fibers installed between two facilities. The cable may be buried directly in the earth, may be installed underground in cable ducts, or may use aerial installation between telephone poles. Once it ingresses a facility, the cable is routed to a distribution shelf which contains splice trays and an optical patch panel. In the distribution shelf, the individual fibers of

the cable are separated and spliced onto fiber pigtails which are routed to the optical patch panel. Individual optical fibers are installed between the patch panel and the optical transmitters and receivers.

(2) Cable faults or breaks may occur in the run between the facilities and are normally caused by external forces acting on the cable (i.e., trenchers, backhoes, etc.). The point of damage will be readily apparent. Other causes of failure may be more subtle, such as ground shift or settling causing a splice to give way. The procedure outlined below will be useful in either case and may save time by avoiding the need to visually inspect a long cable run.

(3) Cable faults may occur inside the facility at either end of the cable run due to degradation of a splice or connection, or accidental breakage of a fiber.

(4) The reader should become familiar with the test equipment identified in chapter 7 of this order.

c. Test Equipment.

(1) The following items of test equipment are required.

(a) OTDR or fault finder.

(b) Optical power meter.

(c) Optical source.

(2) A visual light finder is optional for use in inspecting inside plant cabling.

(3) The following items, normally found in a fiber-optic tool kit, are also required.

(a) Microscope.

(b) Magnifying glass.

(c) Fiber cleaver.

(d) Mirror.

d. Detailed Test Procedure. Two individuals are required to effectively fault locate a fiber-optic cable. A means of communication must be provided between one of the individuals at the transmitter and one troubleshooting along the fiber cable run. This procedure assumes that a fiber-optic link has failed and the services it was providing have been lost. The procedure assumes that the traffic sources feeding the link have been eliminated as a cause of service failure.

(1) If not done automatically, restore service by patching traffic through alternate transmission means.

(2) Ascertain that the optical transmitter is not at fault.

(a) If multiple optical links have failed, all of which use optical fibers run in the same cable or duct, it is safe to assume that the transmitters and receivers have not all failed, and that a cable has been severed.

(b) At the transmitter location, disconnect the fiber-optic cable from the optical transmitter of the link that has failed. Connect an optical power meter to the transmitter output, and verify that output power is within tolerances for the transmitter type.

(3) Using a magnifying glass, inspect the fiber-optic cable connector previously disconnected for signs of dirt or damage. Clean fiber surface of connector using alcohol and lint free pads.

(4) Connect an OTDR to the suspect fiber and measure cable performance as detailed in paragraph 118. Ensure that the OTDR settings are the same as those used to make the most recent baseline OTDR graph. Compare the OTDR graph with the baseline graph kept as site records to locate a fault.

(a) A break in the fiber is normally indicated on the OTDR graph as a sharp spike (due to reflection) in the fiber trace, followed by a large shift lower in the backscatter level. Note that some breaks will not produce the sharp spike, but the shift in backscatter level will always be seen. If the new OTDR graph indicates a break, compare the new graph with the baseline graph.

If the break does not show up in the baseline graph, the break indicated on the new graph may be assumed to be the problem. Proceed to subparagraph (5).

(b) If there is no difference between the two plots, the problem resides at the receiver end of the fiber-optic link. Proceed to subparagraph (7).

(c) If the new graph shows the launch reflection followed by a steady, low backscatter level, the break may be located in the dead zone of the OTDR. Disconnect the optical fiber from the OTDR, and clean all optical interfaces between the OTDR and the optical cable. Reconnect the cable to the OTDR and rerun the OTDR graph. If the same result is obtained, the problem resides at the transmitter end of the fiber-optic link. Proceed to subparagraph (8).

(5) Compare the new graph with the baseline graph again. If the location of the break indicated on the new graph corresponds to the location of a splice or connector on the baseline graph, these items should be visually inspected and corrective action should be taken. Determine the location of the splice or connector from facility drawings, and have one person stay with the OTDR and the other travel to inspect the component involved.

WARNING: OTDR's use lasers as optical sources. Ensure that the OTDR is not providing optical power to the cable while it is being worked on.

(a) If a splice is involved, the existing splice should be removed and a new splice made.

(b) If a connector is involved, take the following action.

1 Remove the connector. Clean the connector and its mate with alcohol and lint free pad. Reconnect the connector and mate. Remeasure cable performance using the OTDR.

2 If the problem is not resolved, disconnect the fiber-optic cable from the OTDR and connect to the optical source. At the connector location, disconnect the connector from its mate and connect it to an optical power meter. If the power meter indicates little or no power, replace the connector. If the power meter indicates a good power level, replace the mating connector.

3 Recheck cable performance using the OTDR.

(6) If the location of the break does not correspond to a connector or splice, set the cursor or marker of the OTDR to the location of the break, and read off the distance of the break from the OTDR location. Review facility drawings to determine an approximate location of the break, and have one person stay with the OTDR and the other travel to the suspected location of the break.

(a) Visually inspect the area of the cable run where the break is suspected. In most cases, the break will be caused by construction in the area, and the break location will be obvious. Also look for any activity in manholes which provide access to the fiber-optic cable.

(b) When the break is located, proceed to subparagraph (9).

(7) Problem at Receiver Location.

(a) At the transmitter location, disconnect the fiber-optic cable from the OTDR and connect it to an optical source.

(b) At the receiver location, disconnect the optical fiber from the receiver. Clean the fiber connector and connect the cable to an optical power meter. Measure the cable loss and compare with site records.

1 If power measured appears normal, clean the optical connector on the receiver. Reconnect ends of the fiber cable to the transmitter and receiver, and check performance of the fiber link. If the link is still out of service, replace the receiver.

2 If little or no power is measured, relocate the power meter to any other access points on the fiber inside the facility such as patch panels, other connectors, etc., to attempt to localize the fault.

(c) If a visual light finder is available, connect its output to the receive end of the cable and visually inspect the cable. Breaks in the fiber will be indicated by the bright red glow of helium-neon (He-Ne) laser light leaking from the cable.

(d) If a visual light finder is not available or does not reveal the fault, connect the OTDR to the receive end of the fiber. Minimize the launch dead zone by setting the OTDR to the minimum pulse width available. Set the OTDR display to zoom in on the area of the cable near the launch reflection to discern the location of the break in the cable from the launch reflection. With a short pulse width, the OTDR should localize the fault to less than four meters of cable.

(e) Once the break has been localized by the OTDR, visually verify its location and proceed to subparagraph (9).

(8) Problem at Transmit Location.

(a) If a visual light finder is available, connect its output to the transmit end of the cable and visually inspect the cable. Breaks in the fiber will be indicated by the bright red glow of He-Ne laser light leaking from the cable.

(b) If a visual light finder is not available or does not reveal the fault, reconnect the OTDR to the fiber. Minimize the launch dead zone by setting the OTDR to the minimum pulse width available. Set the OTDR display to zoom in on the area of the cable near the launch reflection to discern the location of the break in the cable from the launch reflection. With a short pulse width, the OTDR should localize the fault to less than four meters of cable.

(c) Once the fault has been localized by the OTDR, visually verify its location.

(9) The following actions should be taken when a break is found.

WARNING: OTDR's use lasers as optical sources. Ensure that the OTDR is not providing optical power to the cable while it is being worked on.

(a) If the cable is completely severed, cut it back to a point before any visible damage appears. Expose all fibers. For each fiber in turn, measure the amount of the reflection indicated on the OTDR, then place a reflective surface (mirror) against the fiber end and repeat the reflection measurement. If the reflection increases with the reflective surface in place, the cable is sound back to the OTDR. Move the OTDR to the receive end of the link and repeat the reflection measurement for the other end of the break.

(b) If the cable appears only partially severed, strip the outer sheath, any jacket, and steel armor for approximately two feet on either side of the break to expose the fiber tubes. Leave fibers that are intact alone. Repeat the reflection test of step 1 on fibers that are broken.

(c) Repair cable by splicing fibers.

143. SPLICING TECHNIQUES.

a. General. It is not feasible to give detailed splicing procedures in this handbook to cover all situations. These procedures will depend on the fiber-optic cable being spliced, the splice enclosure being used, and the type of mechanical splice or fusion splicer being used. The purpose of this paragraph is to provide generalized procedures in the splicing process which are common to most splicing techniques. The manufacturer's instructions provided with the cable, splicer, and splice organizer should always be carefully reviewed and followed when making a splice.

b. Cable Preparation. Cable preparation involves the measuring, marking, slitting, cutting, and stripping of the cable required prior to actually working with the fiber. It is important for the person making the splice to know how the cable involved is constructed and can do so by referring to manufacturer's documentation. Figure 5-15 shows construction of two typical cables.

(1) Pre-rack both ends of the cable to be spliced in the locations they will occupy when the splice is complete. Determine type and location of splice enclosure to be used. Determine the length of cable required to mount the finished splice, and mark the cables with tape where they will enter the splice enclosure or where they will be secured to the splice enclosure.

(2) Determine the length of bare fiber or buffer tube required for the particular cable and splice organiz-

er being used. Note that some buffer tubes and fibers may need to be longer than others in the cable due to the type of splice organizer used. From the previous tape mark, corresponding to the cable entrance into the splice enclosure, measure toward the end of the cable a length corresponding to the longest bare fiber or buffer tube required, and mark the cable at this location with tape.

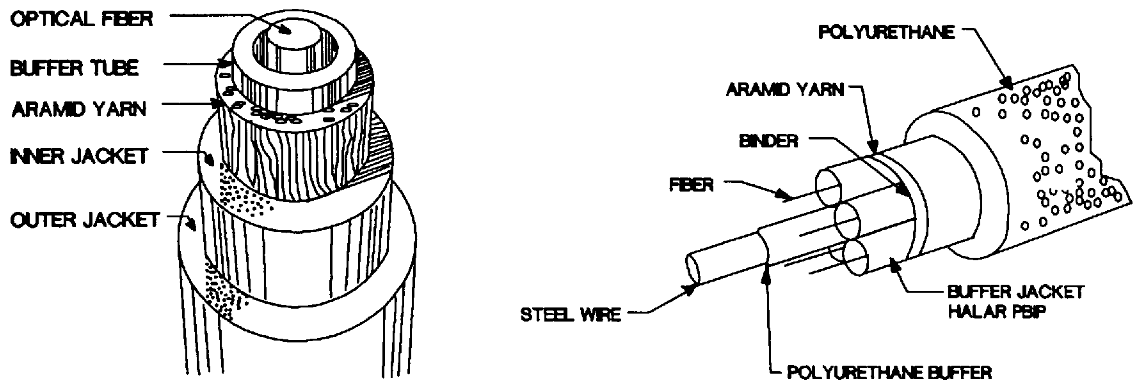


Figure 5-15. Typical Fiber-Optic Cable Construction

(3) Cut excess cable off at the tape mark.

(4) Strip the cable jacket between the two tape marks as follows.

(a) Optical Cable Without Metallic Shield.

1 Remove one-half inch of the outer jacket at the end of the cable and locate the jacket ripcord. Make a small cut along the ripcord axis.

2 Grab the ripcord with a pair of long-nosed pliers. Pull the ripcord at a 90° angle to the cable until the jacket is ripped to the tape mark.

3 Peel back the jacket to expose the inner jacket or cable core, trim the jacket at the tape mark, and remove it.

4 If an inner jacket is present, remove it in the same manner.

5 If no ripcord is present, score the jacket longitudinally with an X-acto knife or razor blade taking care not to penetrate into the cable core damaging the optical fibers.

(b) Optical Cable With Metallic Shield.

1 Using an X-acto knife or razor, carefully make an annular cut (ring cut) through the jacket and score the shield approximately three inches from the cable end. Flex the cable at this point until the shield breaks, and pull off the jacketing and the shield. The ripcord under the shield should then be exposed.

2 Make another ring cut at the tape mark and score the shield, taking care not to damage the fiber. Flex the cable until the shield breaks.

3 Grab the ripcord with a pair of long-nosed pliers. Pull the ripcord until the jacket and shield are ripped to the tape mark, and remove the jacket and shield.

(c) Armor-Shielded Cable. In some cases the aramid yarn will spiral and bond to the shield, necessitating the removal of the outer jacket, shield, and aramid yarn simultaneously.

1 Make a ring cut at the tape mark and score the shield. Flex the cable at the cut until the shield breaks. Bend the cable no more than 45° to expose the aramid yarn. Cut the aramid yarn with an X-acto knife taking care not to damage the fibers.

2 Remove the jacketing from the cable by gently pulling. Only a 24-inch section of cable can be removed at one time to reduce excessive stress that could damage the fibers.

(5) Remove Water-Resistant Compound. In the event that the cable is flooded with a water resistant compound, the compound must be removed. A gelled waterless hand cleaner can be applied from the jacket toward the cable end. Do not wipe from the end toward the jacket as this may kink and break the fibers. With the hand cleaner still on the cable, separate buffers and strength members by gently combing them out in short sections starting at the end of the cable. If this proves difficult, gently untwist them. Wipe each buffer and strength member clean using a soft absorbent cloth.

(6) Mount Cable to Splice Enclosure/Organizer. Trim the strength members of the cable to a length appropriate for the organizer and splice enclosure. Secure the cable and strength member to the organizer in accordance with manufacturer's instructions for the enclosure.

c. Fiber Preparation. Fiber preparation includes the actions to be performed on the individual fibers prior to splicing. This basically consists of removing the buffer and cleaving the fiber.

(1) Remove Buffer. Optical fibers must be stripped of buffer coatings to permit proper cleaving and to fit within splicing devices.

(a) Determine the length of each fiber required for the splice organizer being used, and the amount of buffer to be removed from the fiber for the splice type being used. Consult the manufacturer's information for these dimensions.

(b) Loose Tube Buffer.

1 Remove the loose tube buffer by scoring the buffer tube with a razor and flexing the tube until it breaks. Take care not to cut through the tube as damage to the fibers may result.

2 Gently pull the buffer tube off of the fiber.

3 Remove any gel or powder from the fiber by wiping with a soft cloth.

(c) Tight Buffer. Tight buffers may be removed using either mechanical devices or chemicals.

1 Mechanical. Mechanical strippers are commercially available that are similar to the kind used to remove insulation from thin copper wires. Care must be taken when using these devices to avoid nicking the fiber.

2 Chemical. Buffer coatings can be removed by immersing the fiber in a solvent such as acetone or methylene chloride. If these chemicals are unavailable, a liquid paint remover containing methylene chloride may be used. Soaking time may vary depending on the type and thickness of buffer and the chemical being used. Immersion in acetone may require a minute or more while methylene chloride may require less than 30 seconds. Immediately after immersing, wipe away the buffer using a soft cloth.

(2) Cleave the Fiber. Cleaving the fiber is a method of breaking the fiber in a way to create a smooth, square, flat end on the fiber. Mechanical cleaving tools are commercially available for cleaving fibers. In fact, some fusion splicer manufacturers require the use of cleaving tools specifically developed for use with their equipment. Manufacturers' instructions should be consulted on the use of mechanical cleaving tools. Where a cleaving tool is not available, the following procedure may be used.

(a) Clean the fiber using a lint free cloth and reagent grade alcohol or Freon.

(b) Tape the fiber to a flat surface. The tape should be applied approximately one-half inch from the scribe point.

(c) Scribe the fiber using a sharp blade of hard material such as a gem or tungsten carbide. The scribe is made by lightly touching the fiber at a right angle on the scribe point with the sharp blade. Do not saw the fiber.

(d) Hold the taped end of the fiber on the surface with one finger. With two fingers of the other hand, pull the fiber straight out until it breaks at the scribed point.

(e) Inspect the fiber end surfaces after cleaving using a 30x to 50x hand microscope. Refer to figure 5-16. If the end surface is angular or has lips or chips, recleave the fiber.

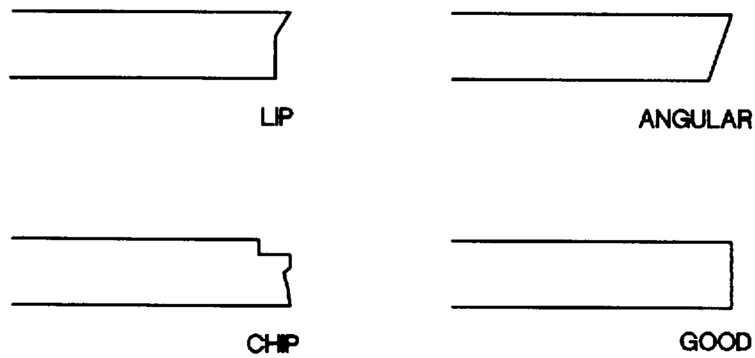


Figure 5-16. Fiber End Surface Examples

d. Splicing Fibers. As was discussed in other parts of this handbook, there are two basic methods of splicing optical fibers, mechanical and fusion.

(1) Mechanical Splicing. Many types of mechanical splices are commercially available today. A mechanical splice typically consists of an assembly which will align and hold the fibers in place. To be effective, a mechanical splice should provide alignment of fibers to be spliced and index matching gel at the splice point. Rotary mechanical splices are not recommended as they require extensive polishing of fiber endfaces. Figure 5-17 shows some mechanical splice device techniques.

NOTE: The manufacturer's procedures should always be followed for the type of splice being used. The following procedure includes those steps that should be common to most splices.

(a) Verify that fiber cleaving has resulted in the right length of bare fiber protruding from the buffer as required for the splicing device.

(b) Clean the fiber ends with reagent grade alcohol and wipe with a lint-free cloth.

(c) Insert one fiber end into the splice to a point corresponding to the center of the splice. Normally, the center of the splice will be marked to serve as a guide.

(d) If the splice device used requires ultraviolet (UV) adhesive to hold the fiber in place, apply it to the fiber at the endface of the splice. Move the fiber back and forth in the splice to ensure the adhesive flows into the splice device. To prevent the UV adhesive from curing prematurely, shade the splice from direct sunlight.

(e) Insert the second fiber into the splice device until it butts against the first fiber. Apply UV adhesive as was done in step 4. Verify good contact by gently pushing on the fiber until a slight buckling of the fiber occurs, then release the pressure.

(f) Examine the arrangement to ensure the fibers are straight and square as they enter the splice.

(g) Optimize the splice by measuring its loss with a power meter and source or OTDR. Back out one of the fibers no more than 1/8-inch, rotate it 90°, and reinsert it until it meets the other fiber. Remeasure the fiber loss. If the loss is less than that measured previously, leave the fibers in place. If the loss has increased, rotate the fiber back to its original orientation.

(h) Cure the splice by exposing it to a UV lamp or curing device for approximately two minutes.

(i) Place the splice in the splice organizer.

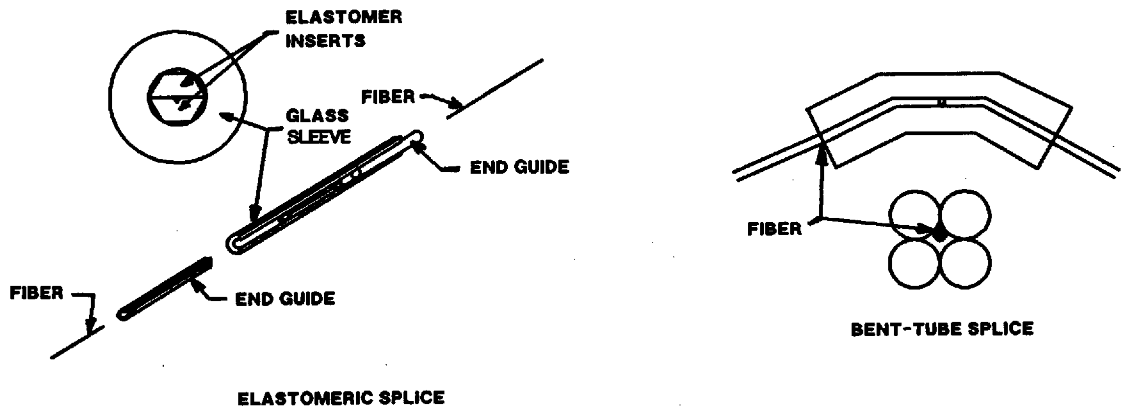


Figure 5-17. Mechanical Splice Devices

(2) Fusion Splicing. Fusion splices are made by positioning cleaned, cleaved, fiber ends between two electrodes and applying an electric arc to weld the ends together. The steps required to make a fusion splice will depend on the type of splicer used, and the manufacturer's operator manual should always be consulted for detailed procedures. However, all splices require the following general steps: alignment, prefusion cleaning, fusion, and splice evaluation.

(a) Consulting the manufacturer's operator manual, set the time and current for the cleaning arc and fusing arc. Settings will depend on the fiber being fused as well as local environmental conditions such as temperature and humidity. Many fusion splicers have preprogrammed settings which should be used as a starting point. If there is any doubt about the proper setting, a sample splice should be made and evaluated.

(b) Verify that fiber cleaving has resulted in the right length of bare fiber protruding from the buffer as required for the fusion splicer being used. Clean the fiber ends with reagent grade alcohol and wipe with a lint-free cloth.

(c) Slide a length of heat-shrinkable tubing over one of the fiber ends. Length of tubing should be sufficient to cover the bare fiber area after splicing has been accomplished.

(d) Position fiber ends in the fiber holders of the fusion splicer. Note that some fusion splicers come with multiple fiber holders, one of which is selected for the fiber being fused and mounted on the splicer.

(e) Align fibers prior to fusing. Note that some splicers will accomplish this automatically using a light injection detection (LID) system or profile alignment system (PAS). Manual alignment may be accomplished using a video display presentation on some splicers or by viewing the fiber ends with a microscope and mirror. By convention, a misalignment identified by a top view of the fiber is said to be in the x-axis while a misalignment identified by a side view of the fiber is said to be in the y-axis. The z-axis lies along the length of the fiber.

1 Manual Alignment Using Video Presentation. (See figure 5-18.)

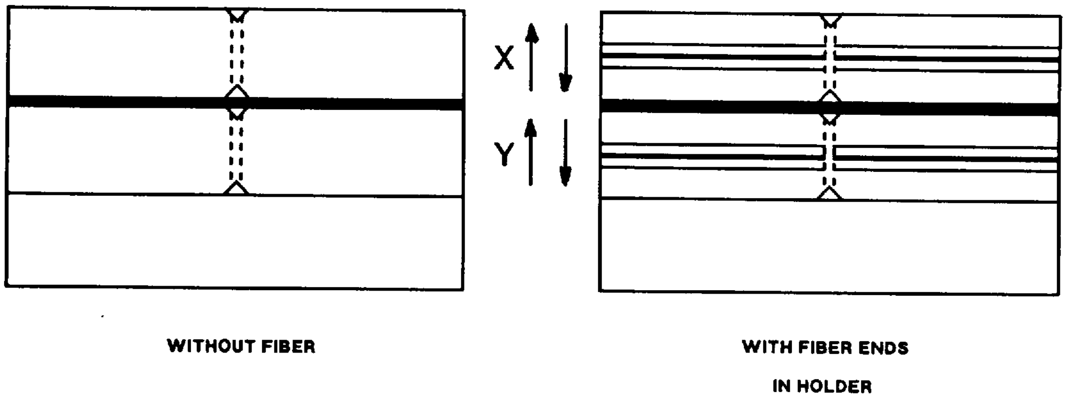


Figure 5-18. Fusion Splicer Video Display Presentation

a Adjust X positioner to align fiber ends in the top part of the video presentation.

b Adjust Y positioner to align fiber ends in the middle part of the video presentation.

c Adjust Z positioner to move the fibers against the vertical dotted lines in the video presentation.

2 Manual Alignment Using Microscope and Mirror. (See figure 5-19.)

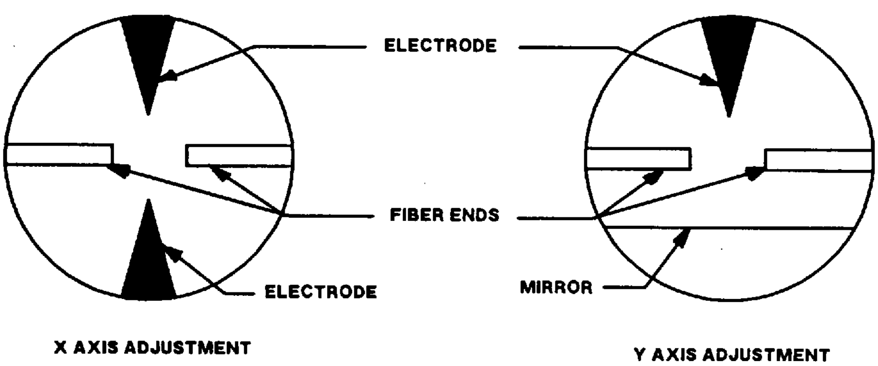


Figure 5-19. Viewing Fiber Ends Through Microscope

a Focus microscope on the electrode tips. Adjust the x-axis positioners to center the fiber gap on the electrode tips and bring the fibers in alignment with each other.

b Rotate mirror to provide side view and refocus as necessary. Adjust the y-axis positioners to center the fiber gap on the electrode tip and bring the fibers in alignment with each other.

c Set z-axis controls as required in the manufacturer's instruction book for prefusing.

(f) Prefuse the fiber ends in accordance with the manufacturer's instruction book for the fusion splicer.

(g) Fuse the fiber ends in accordance with the manufacturer's instruction book for the fusion splicer.

(h) Evaluate the splice through visual observation. In a good splice, the cladding glass surface will be smooth.

(i) Evaluate the performance of the splice. Some fusion splicers have an intrinsic capability to measure the loss of a splice. Where this capability does not exist, the splice should be looked at with an OTDR.

1 If the splice is not of good quality, review the procedure used in making the splice to determine the cause. Break the fiber, recleave the ends on either side of the splice, and resplice the fiber.

2 If the quality of splice is good, slide the heat-shrinkable tubing over the bare fiber to provide some protection, and place the splice in the splice organizer.

144. CABLE TERMINATION.

a. Various connectors are commercially available to terminate fiber-optic cables. Attaching a connector to an optical fiber requires training and special tools. It also requires expertise and the development of technique which can only be gained and maintained through experience and frequent exercise of the connecting procedures. As it is anticipated that a technician will not be required to attach fiber-optic connectors on a frequent basis, it is recommended that requirements to attach a large number of connectors be contracted out to a company that specializes in this area.

b. For the rare instance that a single connector must be replaced or a new fiber terminated, it is recommended that a connector be purchased with a fiber pigtail already attached. The pigtail consists of a short length of fiber-optic cable which has been terminated on one end to the connector by the manufacturer. The other end of the pigtail is then fusion spliced to the fiber being terminated. See figure 5-20. The added loss due to the fusion splice is minimal, and the difficult connecting process is avoided. Connectors with pigtails are readily available from manufacturers. When ordering, ensure that the pigtail length and size and type of fiber to be used are specified.

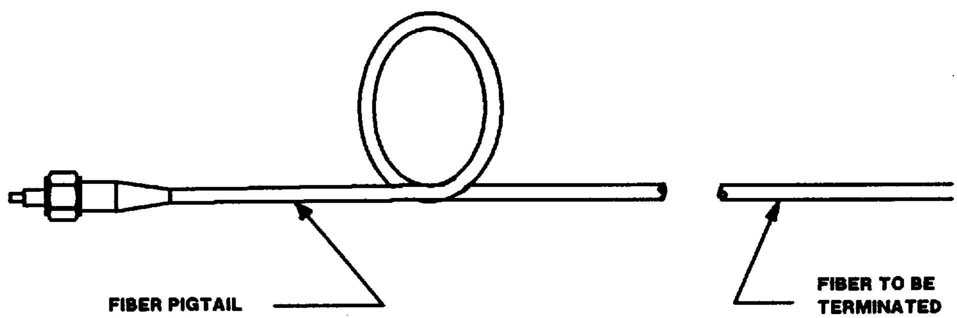


Figure 5-20. Cable Termination Using Connector With Pigtail

145.-155. RESERVED.

CHAPTER 6. FLIGHT INSPECTION

156. GENERAL.

Fiber-optic communications equipment is not flight checked independently, but may be considered an integral part of a radar or air/ground communications channel that is flight checked. Refer to OA P 8200.1, United States Standard Flight Inspection Manual.

157.-160. RESERVED.

CHAPTER 7. TEST EQUIPMENT

161. GENERAL.

Fiber-optic communications requires some unique items of test equipment. This chapter provides information on types of test equipment used for fiber optics, how the test equipment is used, and typical salient characteristics for the test equipment. Information on various manufacturers' test equipment is provided to give the reader a sample of what is presently available. The provision of this information should not be taken as an endorsement of a manufacturer's product.

162. OPTICAL TIME DOMAIN REFLECTOMETERS (OTDR's).

a. Principles of Operation.

(1) The optical time domain reflectometer (OTDR) is a device that characterizes the performance of a fiber-optic cable run. It measures the loss at each splice and connector, measures overall cable run loss, and locates discontinuities (defects) in the cable run. The advantages of using an OTDR are that it requires access to only one end of the fiber and that it presents a 'picture' of the performance of the cable run. The disadvantages of the OTDR are that they are expensive and difficult to use, lack the resolution necessary to determine quality of a new splice, and are not suitable to provide absolute cable run attenuation measurements. This last disadvantage is due to the fact that the OTDR indirectly determines attenuation based on the amount of signal reflected back into its detector.

(2) An OTDR operates by launching a pulse of light into a fiber and measuring the amount of this light pulse that is reflected back from the fiber. Using this information, as well as the time between the launching of the light pulse and the receipt of the reflection, the OTDR presents a graph of return signal level on the vertical axis and distance along the fiber on the horizontal axis. Figure 7-1 provides a basic block diagram for a typical OTDR.

(a) The pulse laser source sends out a pulse of light on command of the processor. The light goes through the coupler to the fiber under test. Lasers, rather than LED's, are used in OTDR's to launch sufficient power into the fiber to ensure that a detectable backscatter level is received.

(b) The coupler takes in light from the source and directs it to the fiber. The coupler also takes in light from the fiber due to backscatter and Fresnel reflections and directs it to the detector. The coupler prevents light from going directly from the source to the detector.

(c) The optical detector converts the optical power received from the fiber under test to a corresponding electrical signal. The detector used in an OTDR is designed to measure the extremely low levels of backscattered light, and therefore often saturates when reflected light from a discontinuity is received. This results in clipping of the detector's electrical output at its maximum level.

(d) The processor tells the laser when to pulse and samples the power levels received from the detector. Using a very accurate clock source, it measures the time difference between when the laser pulses and when the power level is sampled. Multiplying this time difference by the speed of light in fiber yields the round trip distance of the power sample. Dividing by two relates the sample power level to the distance along the fiber from the OTDR. Sampling the detector power level at regular intervals allows the processor to obtain information necessary to graph return signal level versus distance along the fiber.

(e) The display section consists of a cathode ray tube (CRT) screen to provide a picture of the receive signal level versus distance.

(f) Most OTDR's include ancillary capabilities which may be of use. These include a built-in hard copy plotter, magnetic storage media to save graphs, and software to allow presentation and analysis of a graph on a personal computer. Other features may include internal data analysis tools such as cursors or markers and calculation routines to locate features and measure losses. An OTDR is also available as an expansion card for an IBM PC compatible desktop or laptop computer.

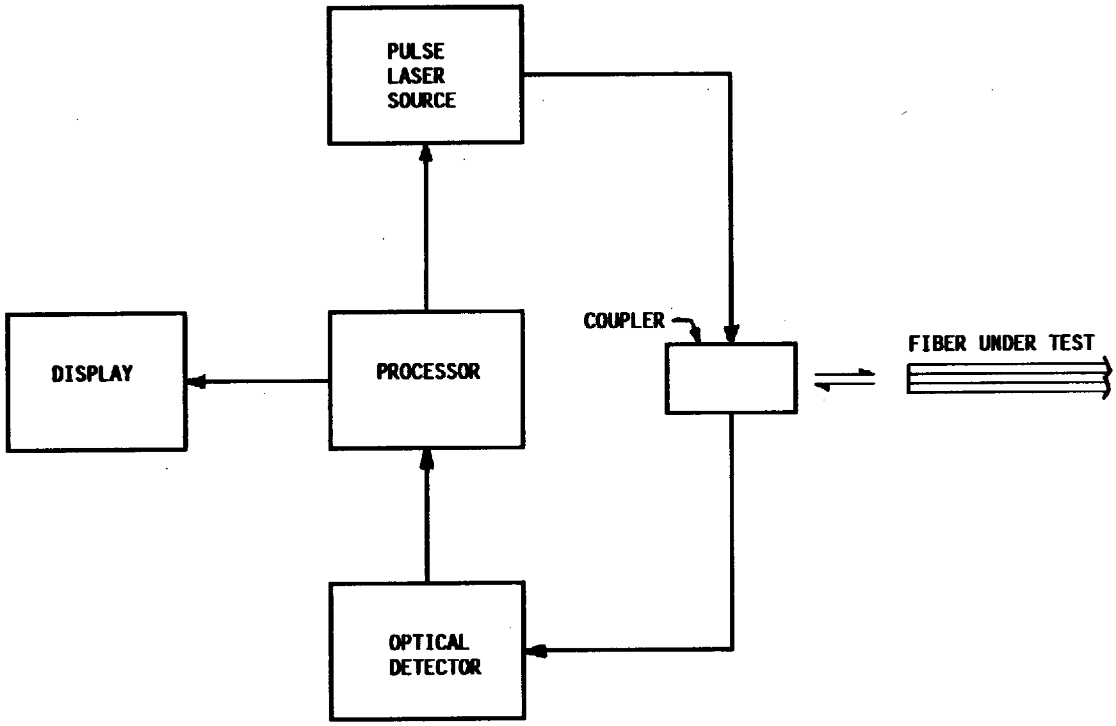


Figure 7-1. OTDR Typical Block Diagram

b. OTDR Terms and Performance Characteristics.

(1) Backscatter. Backscatter is measured by the OTDR to determine loss in fibers, connectors, and splices. As a light pulse travels down a fiber, part of the pulse is scattered by microscopic particles called dopants. These dopants are responsible for the attenuation characteristic of fiber-optic cables. A portion of the light is scattered back in the direction of the transmitter and is detected by the OTDR. This portion is called backscatter. The backscatter is consistent through the length of the fiber and is proportional to the transmit light level and attenuation characteristic of the fiber.

(2) Fresnel Reflection. When light traveling down a fiber encounters a discontinuity such as a connector, splice, end of fiber, or fiber break, some of the light is reflected back toward the source. This type of reflection is called a Fresnel Reflection. The amount of light reflected back is much greater than backscatter light levels, and a Fresnel Reflection shows up on an OTDR plot as a spike. As the plot also contains distance information, the precise location of a fiber break may be determined using an OTDR.

(3) Dead Zone. The dead zone is that portion of the cable run for which features cannot be recorded. The OTDR detector is designed to measure the low backscatter levels from a fiber and becomes saturated when a Fresnel reflection is received. Backscatter information received during this period of saturation is lost. The saturation lasts as long as the pulse duration and detector recovery time. The length of the dead zone is the product of the pulse width plus detector recovery time and the speed of light through the fiber. An important point to remember is that the first part of the fiber will always be a dead zone due to the reflection caused by its connection to the OTDR. To characterize

the fiber portion that is close to the OTDR, the shortest possible pulse width should be used to minimize the length of the dead zone.

(4) Index of Refraction (IOR). The IOR is used in calculating the speed of light through fiber, which is equal to the speed of light through free space divided by the IOR of the fiber. The IOR varies for the different types of fiber and is normally provided by the manufacturer. The value of IOR for the fiber under test must be input into the OTDR to allow it to provide accurate distance information for the fiber.

(5) Pulse Duration. The duration of the pulse is normally selected by the operator for the measurement conditions present. A longer pulse duration couples more power into the fiber, increasing its dynamic range and allowing the testing of longer, more lossy, cable runs. Unfortunately, the longer pulse duration also decreases the distance resolution of the OTDR and increases the dead zone of the measurement.

(6) Dynamic Range. Dynamic range is determined by the total pulse power of the light source and the ability of the optical detector to discern low light levels (sensitivity). The greater the dynamic range, the greater the ability to measure longer cable runs.

(7) Distance Resolution. Distance resolution is the ability of the OTDR to differentiate between two features of a fiber (splices, connectors, etc.). The resolution achievable is dependent on the pulse duration selected and the rate at which the processor samples the detector power. Using a short duration pulse, the OTDR may portray two splices, five meters apart, as separate, distinct, features of a cable run. With a longer duration pulse, the effect of the two splices may be combined into one feature as depicted on the OTDR.

(8) Distance Accuracy. An OTDR specifies the location of features (splices, connectors, breaks) in terms of distance along the fiber. Distance accuracy reflects the error possible in this measurement, and is dependent on the accuracy of the clock source in the processor and errors in setting the index of refraction for the fiber being tested.

(9) Level Resolution. Level resolution is the ability of the OTDR to distinguish between different levels of light power received at the detector. A lack of resolution can inhibit the OTDR from measuring the performance of a splice.

(10) Level Accuracy and Linearity. Data provided by OTDR's should accurately reflect the light levels being reflected back to the detector. Good linearity means that this accuracy is maintained over the dynamic range of the unit. This parameter is especially important when the OTDR is used to measure loss across the fiber.

(11) Wavelength. Multimode fibers work with light in the 850-nm and 1300-nm bands. Single mode fibers use light in the 1300-nm and 1550-nm bands. An OTDR may use interchangeable modules to provide light sources in the different bands, or it may have a module with a dual band capability. The important thing to remember is that loss in fiber is wavelength dependent, and the fiber should be tested using light of the same wavelength as that used in operation.

c. Use of OTDR Graphs.

(1) Typical OTDR Graph. Figure 7-2 shows a typical OTDR graph. The graph shows a picture of the fiber cable, with the beginning of the fiber (the end closest to the OTDR) on the left-hand side of the graph, and the end of the fiber on the right-hand side. Each horizontal division represents 200 meters of fiber while each vertical division represents a 4-dB difference in signal strength. The features, from left to right, are discussed below.

(a) Laser Pulse. Also known as the "launch pulse," this is a Fresnel reflection due to the connection of the OTDR to the fiber. The width of the reflection on the graph is approximately one tenth of a division, which represents 20 meters of cable. Therefore, the first 20 meters of fiber lies in a dead zone, and the OTDR will not depict any features occurring in this part of the cable.

(b) Fusion Splice. The graph indicates that a fusion splice exists approximately 320 meters from the beginning of the cable. Good fusion splices are

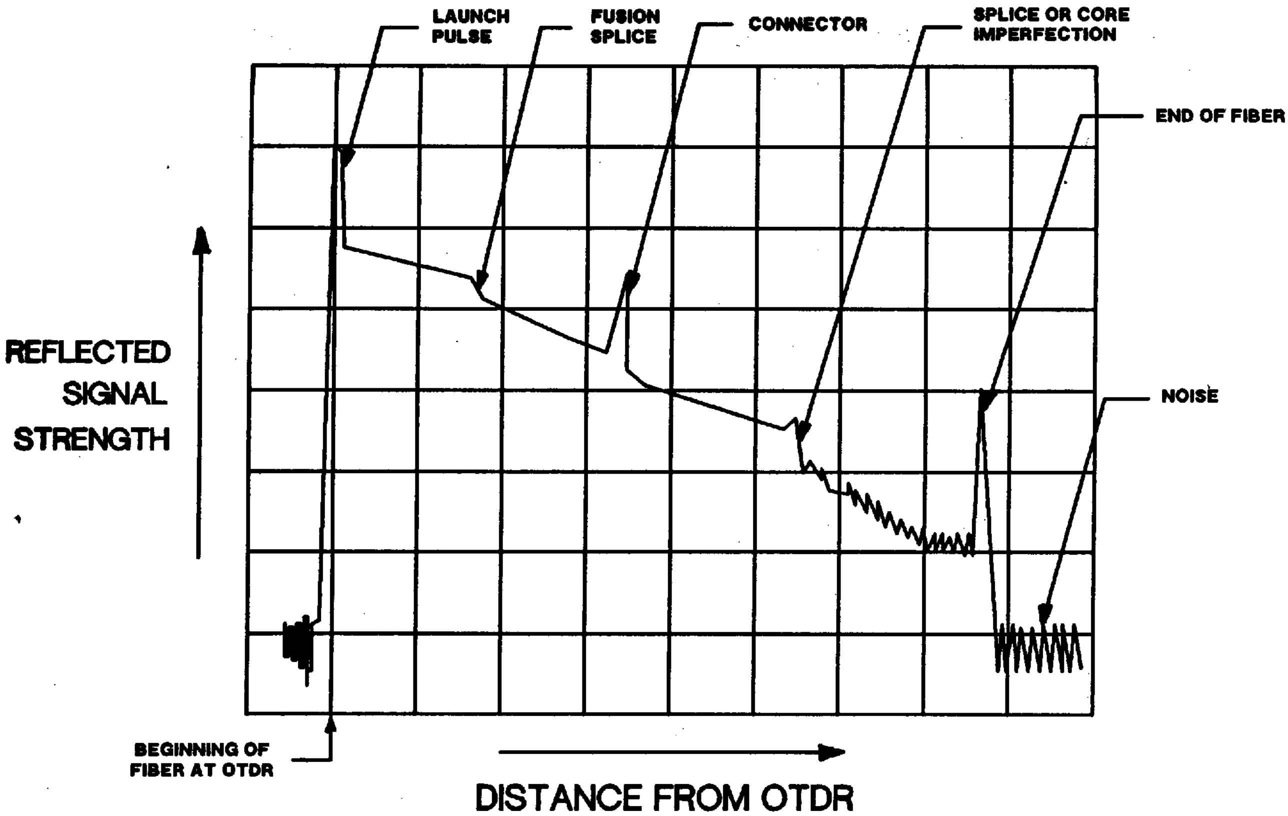


Figure 7-2. Typical OTDR Graph

characterized by slight losses in backscatter levels, but no reflection.

(c) Connector. A connector pair is shown approximately 640 meters from the beginning of the cable. Connectors will create a Fresnel reflection as is shown on the graph. The loss across the connector may be estimated by taking the difference in backscatter power level immediately before and after the reflection.

(d) Splice or Core Imperfection. A mechanical splice or discontinuity in the fiber will create a reflection, the amount of which is dependent on the severity of the discontinuity, among other things. Notice that the graph shows almost a 2-dB loss across this feature.

(e) End of Fiber. The end of the fiber is characterized by a large reflection, followed by a low, steady, noise level corresponding to the noise floor of the OTDR. The graph indicates that the fiber is 1520 meters long.

(2) OTDR Graph with Anomaly. Figure 7-3 is provided as an example of how an OTDR may be used to quickly locate a fault in a fiber-optic cable run. This graph shows the same cable as that of figure 7-2, but is taken after a fault is reported with the cable. The new graph shows that the end of the fiber now appears to be 640 meters from the beginning. A comparison of the two graphs readily indicates that the problem is most likely in the connector pair documented previously.

(3) Measurements Using an OTDR. Manufacturers' operating manuals should be consulted for detailed information on OTDR operation and measurements. The following information is provided as general

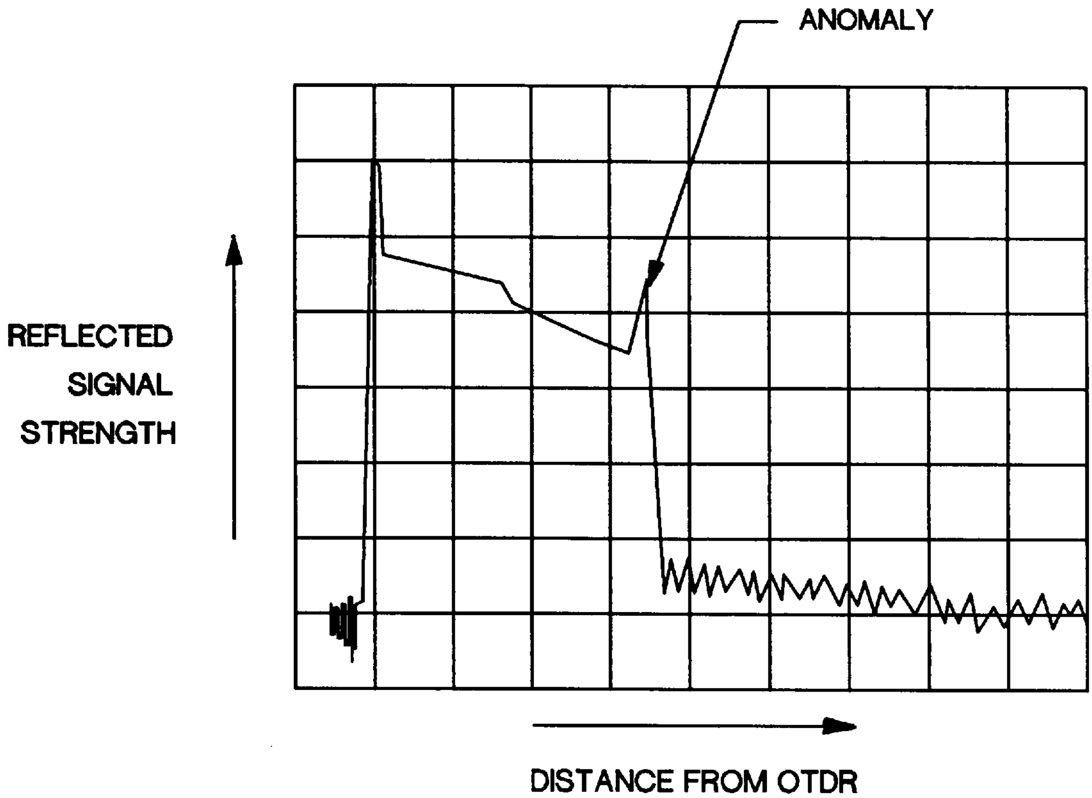


Figure 7-3. OTDR Graph with Anomaly

guidance and applies to most OTDR's in use today. Most OTDR's provide two cursors or markers which may be located on any portion of the graph to identify a feature or boundary. For a position on the graph identified by a cursor or marker location, the OTDR will normally identify the distance along the fiber and the power level. This capability is necessary to make the following measurements.

(a) Fault Location. If a fault is indicated on the fiber graph, place a cursor on the fault and read the location on the OTDR. This corresponds to the distance along the fiber to the fault. Note that this may differ from straight-line distance where a fiber run includes maintenance loops, etc. If possible, locate the fault more precisely by using the shortest possible pulse width and expanding the display to concentrate on the fiber area of concern.

(b) Distance. Two cursors or markers may be used to measure the total length of the fiber or the distance between two features in the fiber. These measurements may be retained for future use.

(c) Fiber Loss. The loss between two points may be measured by placing the cursors or markers on the two points and taking the difference in power level measured at each point. Note that loss can be measured only from backscatter level to backscatter level. Never place a cursor or marker on a reflection when performing loss measurements. This method may be used to measure the loss of the total fiber run or sections of the fiber.

(d) Splice Loss.

1 Splice loss may be measured by the OTDR using a method similar to that for fiber. Place the cursors or markers on the backscatter level just before and just after the splice point, and measure the difference in power level.

2 Note that the shift in backscatter level due to splice loss occurs over a section of cable, with the length of this section corresponding to the pulse width. There is a finite length of cable between the two cursor or marker positions, and the splice loss measured will include the normal loss associated with this length of cable. With large splice losses (i.e., >0.2 dB), this added loss is negligible. However, as splice technology progresses, resulting in decreasing splice losses, the ability of the OTDR to measure splice loss will decrease.

3 An additional inaccuracy affecting splice loss measurements occurs when different types of fibers are spliced together. If the second fiber has a higher backscattering coefficient than the first fiber, more power will be scattered back toward the OTDR, and the OTDR will sense an increase in detected power. This will show up in the graph as a splice "gain," as the backscatter level before the splice will be lower than that after the splice. If the OTDR is put on the other end of the fiber, the splice loss will appear much greater than it actually is.

d. Sample OTDR Manufacturers and Model Numbers. The following lists some OTDR's currently on the market. The list is by no means all inclusive and should not be construed as an endorsement for any manufacturer. It is provided to give a starting point to anyone trying to select an OTDR. Personnel involved in purchasing an OTDR should investigate as many makes and models as time allows. Note that while the basic model number is given, each OTDR will require optional modules to tailor its use to the fibers being tested. Tailoring factors will typically include wavelength, single mode or multimode cable, and cable run (short haul or long haul).

(1) Anritsu Corp Model No. MW98A.

(2) Anritsu Corp Model No. MW910A.

(3) Anritsu Corp Model No. MW920A.

(4) Antel Optronics Inc Model No. AOC10.

(5) Hewlett Packard Model No. HP8146A.

(6) Laser Precision Corp Model No. TD-2000.

(7) Laser Precision Corp Model No. TD-9950.

(8) Laser Precision Corp Model No. TD-9960.

(9) Siecor Model No. 2001HR.

(10) Tektronix TFP2 FiberMaster.

(11) Tektronix Model No. OF150.

163. OPTICAL SOURCES.
Optical sources are used in conjunction with optical power meters to measure the loss of a fiber-optic cable run. They are analogous to signal generators in a copper wire environment. The following characteristics should be considered when selecting an optical source for use.

a. Characteristics.

(1) Source Type. Optical sources may use a light-emitting diode (LED) or laser diode to provide the light source. Laser sources offer higher output levels and therefore may be used to test longer, more lossy, cable runs. Laser sources also provide light with a much narrower spectral width (i.e., a narrower bandwidth) than LED's. LED sources are much less expensive than laser sources and generally have a longer life span. It is recommended that the source type used for testing be the same as the source type used in actual operation.

(2) Wavelength. Optical sources are available in the standard fiber-optic wavelengths of 850 nm, 1300 nm, and 1550 nm. Some sources are available in dual wavelength configurations and may provide 850 nm or

1300 nm light, depending on switch setting. As a fiber may exhibit different loss characteristics for different frequencies, it is recommended that the wavelength of the test source be the same as the wavelength that is normally used in operation.

(3) Output Power. The output power of an optical source should be considered together with the dynamic range of the power meter to be used and the range of fiber attenuation to be measured. In this way the user can ensure that the optical source will always provide a power level at the cable end sufficient for reading by the power meter. Output levels for LED sources will vary from -17 dBm to -35 dBm for portable, ruggedized units. Output levels for laser sources run from +5 dBm to -10 dBm. When analyzing manufacturers' data on sources, remember that the level coupled to the fiber being tested is what counts. An output power specification of "-20 dBm into 62.5/125 micron cable" is not valid if testing 50/125 micron cable. A lower output power (approximately 3-5 dB) would be provided to the 50/125 micron cable.

(4) Fiber Type. Sources are generally made for either multimode or single-mode fibers, but not both.

(5) Stability. A stable optical output over time is required for accurate loss measurements. Presently, a stability of ± 0.1 dB over a one-hour period is easily achievable in a source suitable for field use.

(6) Modulation. Sources provide continuous wave (CW) optical power for use in loss measurements. Some sources are also capable of providing modulated power which may be used for fiber identification.

b. Sample Manufacturers.

(1) Fotec, Inc.

(2) Hewlett Packard

(3) Laser Precision Corporation

(4) Math Associates

(5) Telecommunications Techniques Corporation

(6) 3M Photodyne, Inc.

(7) Wandel & Goltermann

164. OPTICAL POWER METERS.

Optical power meters may be used to measure the output level of an optical transmitter, or may be combined with a stabilized light source to measure loss. Features to look for in power meters are as follows.

a. Features.

(1) Detector Type. Optical power meters use one of three types of detectors. Silicon detectors inherently have low noise and may measure power down to -75 dBm, but are sensitive only to light of approximately 400 nm to 1100 nm wavelength. Germanium detectors respond to light with wavelength from 800 nm to 1800 nm, and therefore may be used with three common fiber-optic bands. These detectors are noisy, however, and are typically limited to measuring signals greater than -65 dBm. Indium-gallium-arsenide (InGaAs) detectors are the newest type detector in use. These units combine the low noise performance of silicon detectors with the wavelength sensitivity of germanium.

(2) Wavelength Calibration. The detectors used in power meters respond differently for different light source wavelengths. A power meter will normally be calibrated for 850-nm, 1300-nm, and 1550-nm light, and the calibration is automatically inserted by the device when the lambda ( ) key is set to the wavelength being used. Some power meters will offer additional calibration points at 10- or 20-nm intervals around the three central wavelengths above. While this feature increases the accuracy of power measurements when laser sources are used, due to their narrow spectral density, it may not be needed when the unit is used with LED sources, whose spectral density may run 50 to 150 nm wide.

(3) Fiber Type. Power meters are normally useable on single-mode and multimode fibers, and on any fiber size.

(4) Dynamic Range. The output of the source to be used in the measurement and the range of attenuation to be measured must be considered in establishing

the dynamic range required of the power meter. A typical optical power meter will measure signals ranging from +5 dBm to -65 dBm.

(5) Accuracy/Linearity. An accuracy of 0.2 dB is normally achievable with a power meter, however, this parameter is normally specified only at one input power level. For accuracy over a given range of input power levels, the linearity of the meter must also be considered. Linearity may add another 0.2 dB of uncertainty to the measurement.

(6) Resolution. Optical power meters will typically read out to 0.01 dB.

(7) Zeroing. Optical power meters may require zeroing before each measurement. This is done by covering the detector and adjusting the unit to 0 watts with no light input. Some meters have an automatic zeroing pushbutton. Others require manually adjusting a trimpot.

(8) DB Reference Capability. Cable loss measurements normally require measuring power in a calibration loop, then measuring the power through the test cable. This capability allows the power meter to store the calibration reading and adjust the test cable power reading to read out the cable loss directly.

(9) Tone. Some power meters use an audio tone which increases in pitch as the signal level increases. This allows a technician to optimize a connection or splice without having to watch the meter.

(10) Connector Type. Most meters are provided with a standard adapter mount. Optional connector adapters are provided to interface the cable connector being tested. Prior to purchase of a unit, a survey should be made of the types of connectors which may be encountered during testing.

(11) Construction. Some optical meters are built primarily for laboratory use and are not ruggedized for the field. Meters should be portable (handheld if possible), be battery operated, and offer some protection from the elements.

b. Sample Manufacturers.

(1) Fotec, Inc.

(2) Hewlett Packard

(3) Laser Precision Corp.

(4) Math Associates

(5) Telecommunications Techniques Corp.

(6) 3M Photodyne, Inc.

(7) Wandel & Goltermann

165. FUSION SPLICERS.

Fusion splicers join two optical fibers by melting the ends together using an electrical arc. Most fusion splicers are compact, light-weight, ruggedized, and battery operated to accommodate use in field environments. Splicers equipped with automatic fiber alignment systems and utilizing microprocessor-controlled fusion will produce a splice with an average 0.5-dB loss.

a. Functions. The units typically provide the following functions: magnified viewing of cleaved ends, alignment of ends, prefusion cleaning of ends, fusing, and evaluation of the splice.

(1) Magnified Viewing of Cleaved Ends. The first step in a good splice is to properly cleave the fibers, ensuring that the cleaves are perpendicular to the axis of the fibers and that the fiber faces are smooth with no chips or tears. Fusion splicers aid in the evaluation of the cleaves by providing a magnified view of the fiber ends. In less expensive units, this is done by incorporating a magnifying scope into the splicer, which allows the user to view the fibers after they have been positioned in the splicer. More expensive units utilize a high resolution video camera and liquid crystal display to provide a picture of the fibers.

(2) Alignment of Fibers. Accurate alignment of fiber ends is absolutely essential to make a good splice. Fusion splicers use three basic methods of performing

this alignment; visual, profile alignment system (PAS), and local injection and detection system (LIDS).

(a) Visual. Visual alignment is the least accurate and least expensive method of aligning fibers. This method requires the user to view the placement of the fiber ends through the magnifying scope and manually position the fibers to obtain what appears to be the best alignment.

(b) Profile Alignment System. The PAS uses parallel light rays passing through the fibers to be spliced at right angles to the fiber axis. The light rays are refracted at different angles depending on the difference in refractive index between the core and cladding, and strike a video camera. This system accentuates the core/cladding boundary and the centerline of the core, and presents a transverse cross-sectional view of the fiber ends on a monitor. This allows accurate alignment of the fiber cores by automatic or manual means.

(c) Local Injection and Detection System. The LIDS uses the principle that light can be launched into and extracted from a fiber core, without removing the primary coating, wherever the fiber is bent in a small radius. Splicers that use the LIDS system put a small bend in each of the fibers to be joined. Light is injected into the fiber at one of the bends and light leakage is detected at the other bend of the fiber. The detected optical power is proportional to the transmission through the splice point, and the fibers are automatically aligned to maximize this transmission.

(3) Prefusion Cleaning of Ends. A good splice requires that the fiber end faces be completely dry and free from dust. The fiber is cleaned with acetone or alcohol and dried with a lint free cloth prior to mounting in the splicer. Fusion splicers further ensure thorough cleaning and drying by passing a short duration prefusing arc at each fiber end. In some fusion splicers, the current and duration of the prefusion must be set by the operator. In newer units, the prefusion is automatically optimized for the type of fiber involved.

(4) Fusing. The success of the actual fusing process is determined by the fusion current level, fusion current duration, gap between fibers, and fiber feed (moving the fibers together) during the fusing. The optimum settings for these parameters will depend on the fiber type and environmental factors. Older, manual, fusion splicers required trial and error settings of these parameters. Newer units automatically optimize these parameters for the type of cable used. Still newer units automatically optimize the parameters for the type of cable, plus they monitor the loss through the splice and automatically cut off the fusing current when the splice is considered optimum.

(5) Evaluation of the Splice. Fusion splices are first visually assessed for quality by the operator. Some splicers also automatically assess splice quality, giving a readout of approximate splice loss. This feature saves time as without it, the splicing task would not be considered complete until a loss or OTDR measurement was made on the cable.

b. Sample Manufacturers.

(1) Alcoa Fujikura, Ltd. Model No. FSM-20CS

(2) Orionics, Model No. FW-310

(3) Siecor Corporation, Model Nos. M-90, M-91, or M-92

(4) Sumitomo, Model No. 35SE-SPH

166. MISCELLANEOUS TEST DEVICES.

a. Fault Finder. Also known as feature finders, these units provide a portable, less expensive alternative to an OTDR when used to troubleshoot a fiber-optic cable. The units operate in the same way as OTDR's, but do not have the data analysis and storage capabilities. Results consist of data on features of the cable such as location, loss, and reflectance level, and are shown on a liquid crystal display. The units are ideally suited for troubleshooting, but not for characterizing a fiber-optic line. The following feature finders are presently available: Fotec Model No. 5600, Laser Precision Model No. FF-1300, and Tektronix TFS 2020 Fiber Scout.

b. Optical Attenuators. Optical attenuators provide a variable attenuation between an optical transmitter and receiver. These devices are useful in determining system power margin when a new fiber-optic link is commissioned, by increasing attenuation until the bit error rate or voice channel is no longer suitable for service. The amount of attenuation inserted is the power margin.

c. Visual Light Finder. This device uses a heliumneon (HeNe) laser to inject visible light into a fiber. The light will radiate at fiber breaks, bad connectors and splices, and microbends, providing a visible indication of problems. These units are useful for indoor fiber-optic cabling, as the light will penetrate most fiber jackets. They are not useful for outside plant cabling as they are limited in distance.

d. Fiber Identifier. A fiber identifier consists of a probe which may be used in conjunction with an optical power meter to detect whether an optical fiber has live transmission, a test signal, or no signal on it. The probe works by clamping on to the fiber, slightly microbending it, and allowing some of the light transmission to leak into the probe's detector. This testing is nondisruptive to traffic.

167. TOOL KIT.

Splicing and attaching connectors to optical fibers require special tools not normally found on the workbench. The specific tools required will depend on the type of connector or splice being used, so a standard detailed list cannot be provided. Most connector and splice manufacturers will sell tool kits made up for use with their products. Items common to most of these kits are as follows.

a. Crimping tool

b. Safety goggles

c. 100x microscope

d. 7x eye loupe

e. Polishing tool

f. Polishing paper (various grits)

g. Polishing glass plate

h. Jacket stripper

i. Buffer stripper

j. Cladding stripper

k. Fiber cleaver

l. Scissors

m. Alcohol bottle

n. Fiber cleaning pads

o. 6-inch scale

p. Epoxy kit with syringe

q. Connector holders

r. Tweezers

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U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject: **INFORMATION:** Suggested Improvements to Order 6650.10, Maintenance of Fiber-Optic Communications Equipment

Date:

From:

____

Signature and Title

Reply to Attn. of:

____

Facility Identifier
AF Address

To: Manager, National Airway Systems Engineering Division, AOS-200

Problems with present handbook.

Recommended improvements.